LONDON-WEST MIDLANDS ENVIRONMENTAL STATEMENT

Volume 5 | Technical Appendices

CFA15 | Greatworth to Lower Boddington

Water resources assessment (WR-002-015)

Water resources

November 2013

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Department for Transport

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1 Introduction

1.1 Structure of the water resources and flood risk assessment appendices

1.1.1 The water resources and flood risk assessment appendices comprise several parts. The first of these is a route-wide appendix (Volume 5: Appendix WR-001-000).

1.1.2 Specific appendices for each community forum area (CFA) are also provided. For the Greatworth to Lower Boddington area (CFA15) these are:

- a water resources assessment (i.e. this appendix);
- a flood risk assessment (Appendix WR-003-015); and
- hydraulic modelling reports for the Culworth Brook at Lower Thorpe (Volume 5: Appendix WR-004-006), the River Cherwell at Edgcote (Volume 5: Appendix WR-004-007) and the Highfurlong Brook (Volume 5: Appendix WR-004-008)

1.1.3 Maps referred to throughout the water resources and flood risk assessment appendices are contained in the Volume 5, Water Resources and Flood Risk Assessment Map Book.

1.2 Study area

1.2.1 CFA15 comprises approximately 17km of route in the Greatworth to Lower Boddington area. The route in CFA15 includes cuttings, embankments and viaducts which have the potential to impact on water resources or flood risk.

1.2.2 The spatial scope of the assessment was based upon the identification of surface water and groundwater features within 1km of the centre line of the Proposed Scheme, except where there is clearly no hydraulic connectivity and in urban areas where the extent was 500m, as outside of these distances it is unlikely that direct impacts upon the water environment will be attributable to the Proposed Scheme. Where works extend more than 200m from the centreline, for example at stations and depots, professional judgement was made in selecting the appropriate limit to the extension in spatial scope. For the purposes of this assessment this is defined as the study area.

1.2.3 The main environmental features of relevance to water resources comprise:

- the River Cherwell (main river from just upstream of Trafford Bridge on the Culworth Brook tributary), Highfurlong Brook (main river) and Boddington Feeder Channel (which feeds the Oxford Canal) and their tributaries;
- the Blisworth Limestone Formation and the Taynton Limestone Formation, which are classified as Principal aquifers;
- a number of Secondary aquifers;
- numerous minor springs, particularly in the Greatworth and Lower Thorpe area; and
- a number of private groundwater abstractions.

1.2.4 The key environmental issues relating to water resources include:

- the need for culvert crossings of watercourses;
- the need for channel diversions on the River Cherwell, Highfurlong Brook and Boddington Feeder Channel;
- the potential impact on groundwater flow to springs near Greatworth, Thorpe Mandeville and Chipping Warden; and
- potential impacts on groundwater flow to private abstractions.

1.2.5 Where there is a residual impact to water resources and following mitigation there is a consequent effect on ecology, this is discussed further in Volume 2, CFA Report 15, Greatworth to Lower Boddington (CFA Report 15), Section 7.

2 Stakeholder engagement

2.1.1 Consultation with the following stakeholders has been undertaken to inform the water resources assessment.

- the Environment Agency; and
- private licensees by informing them of the Proposed Scheme and requesting information on their licensed abstractions in a questionnaire to more accurately assess and understand any potential risks to the private abstraction.

3 Baseline data

3.1 General

3.1.1 The following sub-sections provide a current description of water resources within the study area including surface water and groundwater features.

3.1.2 Most water bodies in this area fall within the River Cherwell sub-catchment of the Thames River Basin District as defined under the Water Framework Directive[1] (WFD) and are covered by the associated River Basin Management Plan[2] (RBMP). To the south and east of the study area, however, the water bodies fall within the Upper and Bedford Ouse sub-catchment of the Anglian River Basin District and are covered by the Anglian RBMP[3].

3.2 Surface water

3.2.1 All surface water features within 1km of the route[4] are presented in Table 1.

3.2.2 The current surface water baseline is shown on Maps WR-01-022 to WR-01-024 (Volume 5, Water Resources and Flood Risk Assessment Map Book). Where a water feature in Table 1 has been given a map reference it appears on one of these maps. The map reference is in one of two forms. If the feature has a specific reference number then this is provided (e.g. a surface water crossing will be referenced as SWC-CFA15-01). If the feature has no specific reference its location on a specific map is provided (e.g. WR-01-024, D6) where D6 is a grid reference using the map specific grid.

3.2.3 The surface water features are based on the Environment Agency's Detailed River Network (DRN) with the addition of water bodies noted on the Ordnance Survey's (OS) 'OS VectorMapDistrict'

[1] European Parliament and European Council (2000). Water Framework Directive - Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, Strasbourg, European Parliament and European Council.
[2] Environment Agency (2009) River Basin Management Plan, Thames River Basin District
[3] Environment Agency (2009) River Basin Management Plan, Anglian River Basin District
[4] The Environment Agency's Detailed River Network (DRN) shows the route to cross a culverted watercourse (Map WR-01-002). The watercourse has been included in the DRN to ensure connectivity. It is considered that any such watercourse is a part of the sewer network and is not a surface water feature. It has therefore not been included in this assessment.

Table 1: Surface water features within the study area in the study area.

Water feature	Location description (Volume 5, Water Resources and Flood Risk Assessment Map Book, map reference)	Watercourse classification[5]	WFD water body and current overall status	WFD status objective (by 2027 as per RBMP)	Receptor value[6]	Q95[7] (m^3/s)	Catchment area at crossing (km^2)	Notes
Tributary of Radstone Brook	A small stream approximately 600m north of the route.	Ordinary watercourse	No status class shown in RBMP – assumed status Moderate	No status class shown in RBMP – assumed status Good potential	Moderate	Not applicable	Not applicable	Runs south-eastwards from Halse Copse woodland to the Radstone Brook on the boundary of the Newton Purcell to Brackley and Greatworth to Lower Boddington study areas.
Unnamed stream - Halse Copse Farm.	A small stream approximately 650m south of the route.	Ordinary watercourse	No status class shown in RBMP – assumed status Moderate	No status class shown in RBMP – assumed status Good potential	Moderate	Not applicable	Not applicable	Rises at springs and runs to the south-west from Halse Copse Farm before joining the unnamed stream rising from springs at Greatworth Fields and flowing eventually to the River Ouse.
Unnamed stream - Greatworth Fields	A small stream approximately 300m south of the route.	Ordinary watercourse	No status class shown in RBMP – assumed status Moderate	No status class shown in RBMP – assumed status Good potential	Moderate	Not applicable	Not applicable	Rises at springs and runs to the south from Greatworth Fields, before joining the unnamed stream from Halse Copse Farm.
Unnamed stream - Greatworth	A small stream approximately 150m south of the route.	Ordinary watercourse	No status class shown in RBMP – assumed status Moderate	No status class shown in RBMP – assumed status Good potential	Moderate	Not applicable	Not applicable	Rises from springs near Greatworth Hall and the disused railway. Runs south-west and then south near Greatworth, before joining the source of the River Great Ouse near Copse Lodge Cottage.

[5] Water-feature classifications: Section 113 of the Water Resources Act 1991 defines a main river as a watercourse that is shown as such on a main river map. Section 72 of the Land Drainage Act 1991 defines an ordinary watercourse as 'a watercourse that is not part of a main river'. Section 221 of the Water Resources Act 1991 defines a watercourse as including 'all rivers and streams, ditches, drains, cuts, culverts, dikes, sluices, sewers (other than public sewers) and passages through which water flows'. Main rivers are larger rivers and streams designated by Defra on the main river map and are regulated by the Environment Agency

[6] For examples of receptor value, see Table 43 in the Scope and Methodology Report (SMR) Addendum, Volume 5: Appendix CT-001-000/2.

[7] Q95 is the flow which is exceeded for 95% of the time (ie. it is a low flow and the river will only have flows less than this for 5% of the time).

Water feature	**Location description (Volume 5, Water Resources and Flood Risk Assessment Map Book, map reference)**	**Watercourse classification[5]**	**WFD water body and current overall status**	**WFD status objective (by 2027 as per RBMP)**	**Receptor value[6]**	**Q95[7] (m^3/s)**	**Catchment area at crossing (km^2)**	**Notes**
Tributary of Helmdon Brook	A small drain approximately 900m north of the route, running north-east near Stuchbury Fox Covert.	Ordinary watercourse	No status class shown in RBMP – assumed status Poor	No status class shown in RBMP – assumed status Good potential	Moderate	Not applicable	Not applicable	The drain rises by the disused railway south of Stuchbury Fox Covert and joins the Helmdon Brook, a small watercourse which runs west to east before joining the River Tove, itself a tributary of the River Great Ouse.
Helmdon Brook	Small watercourse which issues at Painter's Spinney 250m east of the route.	Main river	Helmdon Brook GB105033038230 Poor	Good Potential	High	Not applicable	Not applicable	Helmdon Brook is a small watercourse, which runs west to east before joining the River Tove.
Unnamed pond near Stuchbury Manor Farm	Unnamed pond on the course of the Helmdon Brook approximately 920m north of the route near Stuchbury Manor Farm and Washbrook Spinney (CFA15-P11)	Main river	Helmdon Brook GB105033038230 Poor	Good Potential	High	Not applicable	Not applicable	The unnamed pond is connected to the Helmdon Brook which runs in a west to east direction. It is therefore classified as Main river as part of the Helmdon Brook
Unnamed pond near Astral House	Near Astral House on Helmdon Road (SWC-CFA15-14)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The pond is not connected to any other surface water features in the catchment.

Water feature	Location description (Volume 5, Water Resources and Flood Risk Assessment Map Book, map reference)	Watercourse classification[5]	WFD water body and current overall status	WFD status objective (by 2027 as per RBMP)	Receptor value[6]	Q95[7] (m^3/s)	Catchment area at crossing (km^2)	Notes
Two unnamed ponds - Greatworth	Isolated ponds near nursery to the north of Greatworth, south of the route. (CFA15-P01)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.
Farthinghoe Stream	Approximately 1km south of the route rises near Old Barn Spinney and Keeper's Cottage, west of Greatworth.	Main river	Farthinghoe Stream (Source to Cherwell) and tributaries GB106039037290 Poor	Good	High	Not applicable	Not applicable	Farthinghoe Stream is a small watercourse running south/south-west towards the River Cherwell.
Tributary of Farthinghoe Stream	Rises at Marston Hall Farm	Ordinary watercourse	No status class shown in RBMP – assumed status Poor	No status class shown in RBMP – assumed status Good	Moderate	Not applicable	Not applicable	Short tributary to the Farthinghoe Stream.
Three source streams of River Cherwell the largest of which is referred to as the Culworth Brook	Culworth Brook will be crossed by the route three times at Lower Thorpe. (SWC-CFA15-01 to SWC-CFA15-03)	Ordinary watercourse	Cherwell (Ashby Brook to Cropredy) GB106039037350 Poor	Good	High	0.0002	<0.5 - 2.28	The route will cross several minor unnamed watercourses that rise from springs close to the route. These watercourses and a number of online ponds (see below) join to form tributary of the River Cherwell. The tributary flows northwards and then north-westwards to join the River Cherwell just upstream of Trafford Bridge. At SWC-CFA15-01 the route will cross a

Water feature	Location description (Volume 5, Water Resources and Flood Risk Assessment Map Book, map reference)	Watercourse classification[5]	WFD water body and current overall status	WFD status objective (by 2027 as per RBMP)	Receptor value[6]	Q95[7] (m^3/s)	Catchment area at crossing (km^2)	Notes
Unnamed source stream of Culworth Brook	The unnamed streams will be crossed twice north-west of Lower Thorpe (SWC-CFA15-04 and SWC-CFA15-05)	Ordinary watercourse	No status shown in RBMP - assumed status Poor	No status shown in RBMP - assumed status Good	Moderate	0.0004	3.9	spring.
Tributary of River Cherwell from Danes Moor	Crossed by the route near Trafford Bridge (SWC-CFA15-06)	Ordinary watercourse	No status shown in RBMP - assumed status Poor	No status shown in RBMP - assumed status Good	Moderate	0.0005	5.74	
Six ponds adjacent to tributary of the River Cherwell	Approximately six medium to large sized ponds adjacent to the route near Lower Thorpe Farm. (SWC-CFA15-15 to SWC-CFA15-17 and SWC-CFA15-19) (CFA15-P04)	Ordinary watercourse	No status class shown in RBMP – assumed status Moderate	No status class shown in RBMP – assumed status Good	High	Not applicable	Not applicable	Five of the six ponds appear to be connected to the source streams of the River Cherwell tributary and are thus considered online.
Eleven unnamed ponds - Thorpe Mandeville	In and around Thorpe Mandeville to the south of the route.	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.

Water feature	Location description (Volume 5, Water Resources and Flood Risk Assessment Map Book, map reference)	Watercourse classification[5]	WFD water body and current overall status	WFD status objective (by 2027 as per RBMP)	Receptor value[6]	Q95[7] (m^3/s)	Catchment area at crossing (km^2)	Notes
Unnamed pond west of Culworth	Isolated field pond approximately 1km north of the route, east of the disused railway and to the west of Culworth. (CFA15-P12)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The pond is not connected to any other surface water features in the catchment.
Two unnamed ponds - Wadground Barn	Isolated field ponds adjacent to, and within 600m of the route, south of Wadground Barn. (SWC-CFA15-20)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment, one will be crossed by the route.
River Cherwell	Crossed by the route twice times near Trafford Bridge (SWC-CFA15-07 and SWC-CFA15-21)	Main river	Cherwell (Ashby Brook to Cropredy) GB106039037350 Poor	Good	High	0.007	78.11	The River Cherwell flows to the west and then south towards Banbury. Due to its meandering course the route will cross the River Cherwell twice at this location.
Tributary of River Cherwell (Welsh Road)	Stream runs generally south from Welsh Road to the north of the route; will be crossed by the route south-east of Blackgrounds Farm. (SWC-CFA15-08)	Ordinary watercourse	No status class shown in RBMP – assumed status Poor	No status class shown in RBMP – assumed status Good	Moderate	0.0003	3.3	Subsequently joins the River Cherwell at Osierbed Spinney. Stream contains two small connected ponds along the route.

Water feature	**Location description (Volume 5, Water Resources and Flood Risk Assessment Map Book, map reference)**	**Watercourse classification[5]**	**WFD water body and current overall status**	**WFD status objective (by 2027 as per RBMP)**	**Receptor value[6]**	**Q95[7] (m^3/s)**	**Catchment area at crossing (km^2)**	**Notes**
The Pool - Edgcote	Large water body located 500m south of the route near Edgcote House (CFA15-P05)	Ordinary watercourse	No status class shown in RBMP – assumed status Poor	No status class shown in RBMP – assumed status Good	Moderate	Not applicable	Not applicable	'The Pool' is linked to the channel of the River Cherwell and potentially used for local recreation. There are a number of small drains connecting 'The Pool' with the River Cherwell.
Six unnamed ponds - Chipping Warden	In and around Chipping Warden south of the route. (CFA15-P06)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are potentially connected to the River Cherwell to the south via small drains.
Unnamed pond at Calves Close Spinney	Unnamed pond approximately 230m north of the route near Calves Close Spinney. (CFA15-P13)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The pond has an outlet to the tributary of the River Cherwell (Welsh Road) but is not online to this watercourse.
Unnamed drain Aston le Walls	Located to the south and west of Aston le Walls	Ordinary watercourse	No status class shown in RBMP – assumed status. Good	No status class shown in RBMP – assumed status. Good	Moderate	Not applicable	Not applicable	The drain runs west from Aston le Walls into the Highfurlong Brook.
Sixteen ponds - Aston le Walls	Located to the south and west of Aston le Walls (CFA15-P07)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.

Water feature	Location description (Volume 5, Water Resources and Flood Risk Assessment Map Book, map reference)	Watercourse classification[5]	WFD water body and current overall status	WFD status objective (by 2027 as per RBMP)	Receptor value[6]	Q95[7] (m^3/s)	Catchment area at crossing (km^2)	Notes
Unnamed pond - Aston le Walls	Isolated field pond on the route, to the south-west of Aston le Walls. (CFA15-P08)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The pond is not connected to any other surface water features in the catchment.
Unnamed pond - the Highfurlong Brook	On the route, adjacent to the Highfurlong Brook. (SWC-CFA15-25) (CFA15-P09)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The pond is on the edge of the floodplain of the Highfurlong Brook and will be connected at times of high flood but not in the low to mean flow conditions.
Highfurlong Brook.	Will be crossed by the route to the west of Aston le Wells (SWC-CFA15-09)	Main river	Highfurlong Brook (Source to Wormleighton) GB106039042660 Good	Good (by 2015)	High	0.002	22.93	A small watercourse flowing south-west or south eventually joining the River Cherwell at Cropredy.
Unnamed drain - Highfurlong Brook	Approximately 500m south-west of the route.	Ordinary watercourse	No status class shown in RBMP – assumed status. Good	No status class shown in RBMP – assumed status. Good	Moderate	Not applicable	Not applicable	Runs south-eastwards into the Highfurlong Brook.

Water feature	Location description (Volume 5, Water Resources and Flood Risk Assessment Map Book, map reference)	Watercourse classification[5]	WFD water body and current overall status	WFD status objective (by 2027 as per RBMP)	Receptor value[6]	Q95[7] (m^3/s)	Catchment area at crossing (km^2)	Notes
Unnamed drain at Lower Boddington	Will be crossed by the route south of Lower Boddington. (SWC-CFA15-10)	Ordinary watercourse	No status class shown in RBMP – assumed status. Good	No status class shown in RBMP – assumed status. Good potential	Low	0.00007	<0.5	This watercourse runs south from the Boddington Feeder (for the Oxford Canal) towards Springfield Farm where it peters out.
Eight unnamed ponds – Boddington.	In and around the Boddington area within 1km, north of the route. (CFA15-P10)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.
Boddington Feeder (Oxford Canal).	Will be crossed by the route to the west of Lower Boddington near Fir Tree House. (SWC-CFA15-11)	Artificial	Boddington Feeder (Oxford Canal) GB806100002 Good	Good potential (by 2015)	High	0.0004	4.86	Within 1km north and south of the route five drains run into the canal in the Boddington area. The Boddington Feeder (for the Oxford Canal) is an artificial water body running westwards from Boddington Reservoir to the north of the route into the Oxford Canal summit pound to the north of Claydon.
Unnamed tributary of the Boddington Feeder (Oxford Canal).	Crosses the route to the west of Lower Boddington, immediately west of the Boddington Feeder Channel proper. (SWC-CFA15-12)	Ordinary watercourse	No status class shown in RBMP – assumed status. Good	No status class shown in RBMP – assumed status. Good potential	Moderate	0.00006	0.61	Tributary rising at The Three Ways west of Upper Boddington and flowing south-eastwards from Spella House towards Fir Tree House where it joins another tributary immediately upstream of the Boddington Feeder (Oxford Canal).

Water feature	Location description (Volume 5, Water Resources and Flood Risk Assessment Map Book, map reference)	Watercourse classification[5]	WFD water body and current overall status	WFD status objective (by 2027 as per RBMP)	Receptor value[6]	Q95[7] (m^3/s)	Catchment area at crossing (km^2)	Notes
Unnamed tributary of the Boddington Feeder (Oxford Canal)	Will be crossed by the route near Fir Tree House and further upstream near Fox Covert. (SWC-CFA15-13, SWC-CFA-26 and SWC-CFA-27, SWC-CFA15-29 and SWC-CFA15-30)	Ordinary watercourse	No status class shown in RBMP – assumed status. Good	No status class shown in RBMP – assumed status. Good potential	Moderate	0.0004	4.86 Downstream crossing point (SWC-CFA15-26)	Rises near Fox Covert and flows south and then south-eastwards parallel to the route to Fir Tree House. The watercourse will be crossed by the route twice and by the re-aligned Boddington and Claydon roads three times.
Two unnamed ponds east of Fox Covert	Unnamed ponds are approximately 220m and 490m north of the route, to the east of Fox Covert. (CFA15-P14)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.
Two unnamed ponds south of Fox Covert	Unnamed ponds are approximately 85m and 150m south of the route, to the south of Fox Covert. (SWC-CFA15-28 and CFA15-P15)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment. They are adjacent to the unnamed drain of the Boddington Feeder south of the route.

3.2.4 Table 2 summarises the details for the one surface water abstraction licence within the study area[8]. There is the potential for further unlicensed abstractions to exist, as a licence is not required for abstraction volumes below 20m³ per day.

Table 2: Licensed surface water abstractions

Licence identifier (map reference number and Environment Agency reference)	Distance and direction from route (m)	Abstraction source	Maximum annual abstraction quantity (m^3)	Max daily abstraction quantity (m^3/d)	Purpose
SWA12 (28/39/14/0202)	157m (south-west)	River Cherwell	63	Unknown	Private Household supply

3.2.5 Table 3 summarises the surface water discharge consents within the study area.

Table 3: Surface water discharge consents

Reference number	Permit identifier	Distance (and direction) from route (m)	Discharge type	Receiving water body
CFA15WD18	CSSC.1446	167m (south-west)	Sewage discharge - final/treated effluent	Culworth Brook
CFA15WD70	CAWM.1172	10 (west)	Sewage discharge - final/treated effluent	Culworth Brook
CFA15WD86	TEMP.2957	167 (south-west)	Public sewage - storm overflow	Culworth Brook
CFA15WD87	NPSWQD008441	254 (south-west)	Sewage discharge - final/treated effluent	Tributary of River Cherwell
CFA15WD57	TEMP.2360	647 (north-east)	Public sewage - storm overflow	Highfurlong Brook
CFA15WD69	CNTD.0040	727 (north-east)	Sewage discharge - final/treated effluent	Tributary of Highfurlong Brook
CFA15WD27	CATM.3270	678 (north-east)	Sewage discharge - final/treated effluent	Tributary of Highfurlong Brook
CFA15WD 59	TEMP.2401	426 (north-east)	Public sewage - storm overflow	Boddington Canal Feeder
CFA15WD71	CNTW.0359	164 (north-east)	Sewage discharge - final/treated effluent	Boddington Canal Feeder
CFA15WD82	TEMP.0806	974 (north-east)	Sewage discharge - pumping station	Farthinghoe Stream

3.3 Groundwater

3.3.1 A summary of the geological units present in the study area, along with their hydrogeological characteristics, is presented in Volume 2, CFA Report 15, Section 13.3.

[8] Surface water abstractions for public supply are not included.

3.3.2 Map WR-02-015 (Volume 5, Water Resources and Flood Risk Assessment Map Book) illustrates the spatial distribution of the uppermost superficial and bedrock formations within CFA15. A schematic cross-section along the line of the route in this area showing geological strata, any known groundwater elevations and the vertical location of the Proposed Scheme is presented in Figure 1.

3.3.3 The superficial deposits comprise Alluvium, Head and Diamicton. The Alluvium and Head tend to be highly permeable and form a shallow aquifer classed as a Secondary Type A or Secondary (undifferentiated) superficial aquifer. This shallow aquifer is typically in hydraulic continuity with the local watercourses. It receives both urban and natural recharge, and infiltration from streams. The variable lithology Diamicton is generally of poor permeability and is classified as Unproductive.

3.3.4 The outcropping bedrock comprises the Great Oolite Group underlain by the Inferior Oolite Group. The Great Oolite Group consists mainly of limestone with some mudstone and sand formations. The formations are designated as Principal and Secondary aquifers with the Great Oolite and Taynton Limestone Formations designated as Principal aquifers. In some situations the Great Oolite Group behaves like a receptacle with a fixed volume; once water levels reach a particular height, water drains off via fractures or discharges as springs.

3.3.5 The Rutland and Horsehay Sand Formations (both part of the Great Oolite Group) are classified as Secondary Type B and Type A aquifers respectively. The transmissivity varies from 37 - 825 m^2/d with a mean transmissivity of 212 m^2/d (British Geological Survey (BGS), 1997[9]).

3.3.6 The Horsehay Sand Formation is the lowest formation in the Great Oolite Group and comprises sand and sandstone with thin mudstone and siltstone beds. Due to the thinness of the mudstone bands leakage occurs between the Great Oolite Group and underlying Inferior Oolite Group formations.

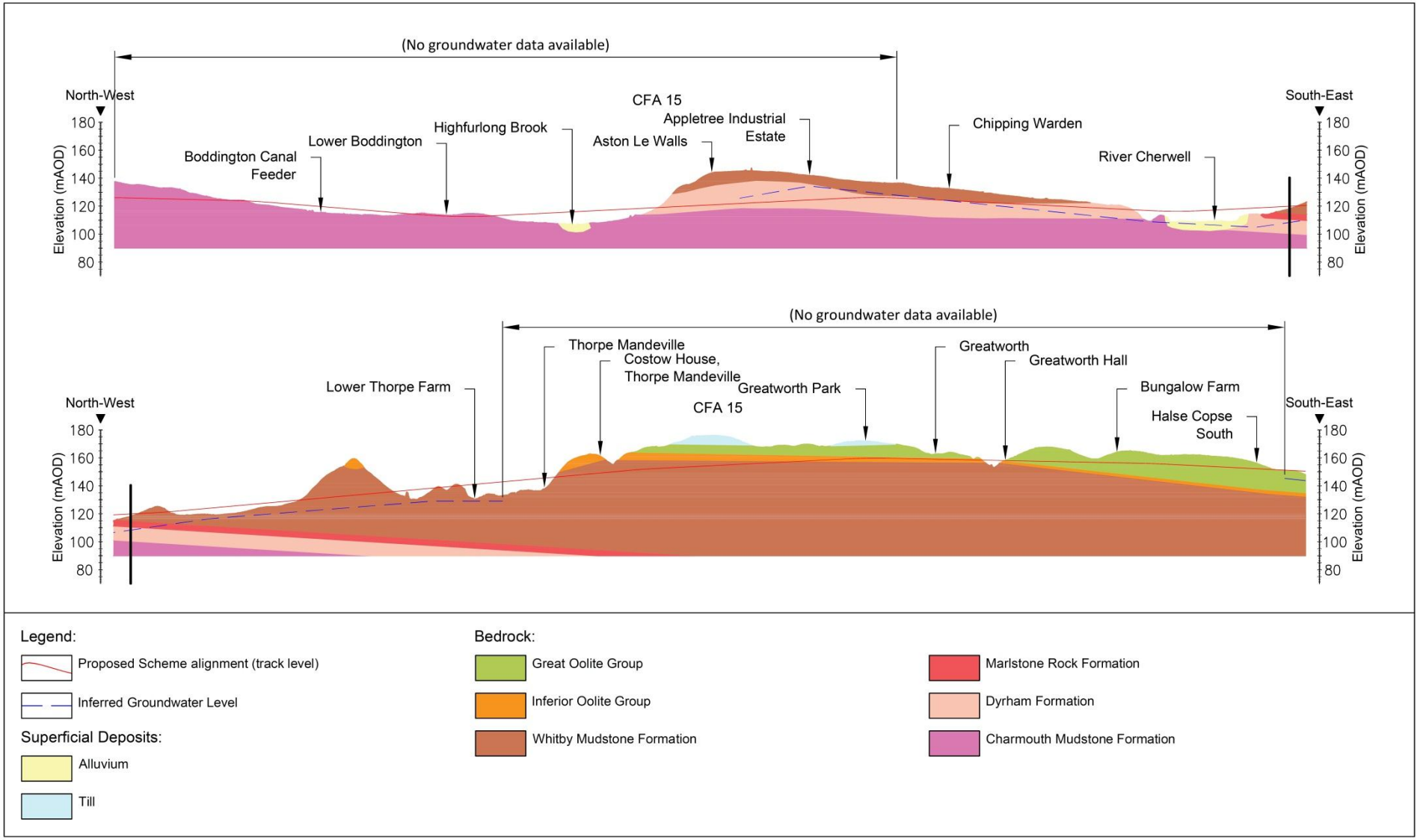
3.3.7 The Inferior Oolite Group forms a Principal aquifer. The transmissivity is generally lower than the overlying Great Oolite and varies from 3 - 700m^2/d with an average of 139m^2/d (BGS, 1997[9]).

3.3.8 Abstraction from the Inferior Oolite has shown a rapid and significant effect on river flows. Water quality in the Inferior and Great Oolite Groups is very similar with typical calcium-carbonate dominated unconfined water and sodium-bicarbonate dominated confined water.

3.3.9 The Lias Group underlies the Inferior Oolite Group. The Whitby Mudstone Formation is the top unit of the Lias Group and is an aquitard (classified as Unproductive strata). Below this are the Marlstone Rock and Dyrham Formations which are classified as Secondary aquifers, with transmissivities which vary from 1.8 m^2/d - 600 m^2/d (BGS, 1997[9]). The underlying Charmouth Mudstone Formation is an aquitard (classified as Unproductive strata).

[9] British Geological Survey (BGS), 1997. The aquifer properties of major aquifers in England and Wales. Technical Report WD/97/34, Environment Agency R&D Publication 8.

Figure 1: Schematic geological cross-section for CFA12.



3.3.10 Table 4 summarises unlicensed and licensed groundwater abstractions within the study area. There are no source protection zones (SPZ) associated with public water supplies (PWS) in the study area. There is the potential for further unlicensed abstractions to exist, as a licence is not required for abstraction volumes below 20m³ per day.

Table 4: Summary of groundwater abstractions

Licence identifier (map reference number and Environment Agency reference)	Distance and direction from route (m)	Abstraction horizon	Maximum annual abstraction quantity (m^3)	Maximum daily abstraction quantity (m^3/d)	Purpose	Number of boreholes
PWS						
There are none in this study area						
Private licensed water supplies (Environment Agency records)						
GWA4a (28/39/14/0177)	348 (west)	Unknown (assumed Dyrham Formation)	10,600	Unknown	Private, unknown	4[a] (2 are >1km)
GWA5a (28/39/14/0177)	756 (west)	Unknown (assumed Dyrham Formation)	10,600	Unknown	Private, unknown	4[a] (2 are >1km)
GWA14 (28/39/14/0298)	906 (west)	Unknown	2,986	Unknown	Private, unknown	1
Private unlicensed water supplies[b]						
CFA15-GWUA01	233 (east)	Unknown, spring	100,320	Unknown	Farm	Unknown
CFA15-GWUA03	616 (east)	Unknown, spring	102,600	Unknown	Farm	Unknown
CFA15-GWUA04	856 (west)	Unknown	106,040	Unknown	Farm	Unknown

[a] One abstraction licence with four abstraction locations, two of which are beyond 1km of the route
[b] Source: Cherwell District Council and South Northamptonshire District Council

3.3.11 Table 5 summarises groundwater discharge consents to groundwater, directly or via land, within the study area.

Table 5: Discharge consents to groundwater

Reference number	Permit identifier	Distance (and direction) from route (m)	Discharge type	Receiving strata / water body
CFA15-WD24	CTWC.1478	512 (south-west)	Sewage discharges - final/treated effluent - not water company	Northampton Sand Formation
CFA15-WD14	CNTM.0103	11 (north-east)	Sewage discharges - final/treated effluent - not water company	Upper Lias
CFA15-WD76	CTWC.0305	760 (south-west)	Sewage discharges - final/treated effluent - not water company	Northampton Sand Formation
CFA15-WD9	CTWC.0964	300 (north-east)	Sewage discharges - final/treated effluent - not water company	Upper Lias
CFA15-WD56	CAWM.0476	164 (north-east)	Sewage discharges - final/treated effluent - not water company	Unknown

Reference number	Permit identifier	Distance (and direction) from route (m)	Discharge type	Receiving strata / water body
CFA15-WD72	CAWM.1200	452 (south-west)	Sewage discharges - final/treated effluent - not water company	Marlstone Rock Formation
CFA15-WD74	CNTM.0826	453 (south-west)	Sewage discharges - final/treated effluent - not water company	Marlstone Rock Formation
CFA15-WD5	CTWC.0993	388 (north-east)	Sewage discharges - final/treated effluent - not water company	Lower Lias Clay
CFA15-WD4	CTWC.2745	603 (north-east)	Sewage discharges - final/treated effluent - not water company	Upper Lias

3.4 Surface water/groundwater interaction

3.4.1 Table 6 summarises the surface water/groundwater interactions within the study area.

Table 6: Surface water/groundwater interaction

Location description (and map reference)	Distance (m) and direction from route	Formation	Approximate elevation (m AOD)	Comments
Issues approximately 300m to the south of Halse Copse, approximately 1.3km north-east of the village of Halse (Map WR-02-015, I6)	Approximately 100m to the south-west of the Proposed Scheme	Blisworth Limestone/ Rutland Mudstone	150	Groundwater flow in Blisworth Limestone assumed to follow topography. In this area flow is likely to be from the higher ground to the west
Springs to the south of Halse Copse Farm and east of Copse Lodge Cottage. (Map WR-02-015, I6)	Approximately 800m to the south-west of the Proposed Scheme.	Horsehay Formation/ Whitby Mudstone	140 to 145	Flow from the spring comes from the underlying Horsehay Sand Formation.
Spring immediately south-east of Bungalow Farm, north of Halse Copse (Map WR-02-015, H5)	Approximately 550m to the north-east of the Proposed Scheme	Blisworth Limestone/ Rutland Mudstone	163	Groundwater flow in the Blisworth Limestone is controlled by topography. In this area flow is likely to be from the high ground to the west
Spring at Greatworth Fields, north-west of Halse Copse Farm (Map WR-02-015, H6)	Approximately 280mto the south-west of the Proposed Scheme	Horsehay Formation/ Whitby Mudstone	150	Groundwater flow is likely to be from the northeast. Cutting through Taynton Limestone in this area is likely to intercept some groundwater flow to the spring.
Issues approximately 300m south-west of Greatworth Hall (Map WR-02-015, H5)	Approximately 100m to the south-west of the Proposed Scheme	Northampton Sand Formation/ Whitby Mudstone	150	Groundwater flow likely to be from the northeast.

Location description (and map reference)	Distance (m) and direction from route	Formation	Approximate elevation (m AOD)	Comments
Spring at disused railway embankment between Greatworth Hall and Stuchbury Fox Covert (Map WR-02-015, H5)	Approximately 750m north-east of the Proposed Scheme	Northampton Sand Formation/ Whitby Mudstone	150	Groundwater flow through Taynton Limestone, Horsehay and Northampton sand in this area likely controlled by topography and be from the south.
Issues at Floyd's Farm (Map WR-02-015, H6)	Approximately 1km south-west of the Proposed Scheme	Northampton Sand formation/ Whitby Mudstone	150	Groundwater flow from north through Taynton Limestone, Horsehay and Northampton sand in this area likely controlled by topography.
Issues south of Greatworth, approximately 130m north of Greatworth Sewage Works. (Map WR-02-015, H6)	Approximately 1km south-west of the Proposed Scheme	Northampton Sand formation/ Whitby Mudstone	145	Groundwater flow from north through Taynton Limestone, Horsehay and Northampton sand in this area likely controlled by topography.
Springs and issues at Oldbarn Spinney (Map WR-02-015, G6)	Approximately 650m south-west of the Proposed Scheme	Northampton Sand formation/ Whitby Mudstone	150 to 155	Groundwater flow from north through Taynton Limestone, Horsehay and Northampton sand in this area is likely to be controlled by topography.
Issues at Painters Spinney (Map WR-02-015, G5)	Approximately 250m north-east of the Proposed Scheme	Northampton Sand formation/ Whitby Mudstone	162	Groundwater flow is likely to be from the south.
Springs and issues at Keepers Cottage, west of Greatworth (Map WR-02-015, G6)	Approximately 1km south-west of the Proposed Scheme	Northampton Sand formation/ Whitby Mudstone	145	Groundwater flow from north through Taynton Limestone, Horsehay and Northampton Sand in this area is likely to be controlled by topography.
Issues approximately 480m south-west of Magpie Farm (Map WR-02-015, G6)	Approximately 270m north-east of the Proposed Scheme	Northampton Sand formation/ Whitby Mudstone	150	Groundwater flow from north through Taynton Limestone, Horsehay and Northampton sand in this area is likely to be controlled by topography.
Issues East of Costow House, Thorpe Mandeville (Map WR-02-015, G6)	Will be crossed by the Proposed Scheme.	Northampton Sand formation/ Whitby Mudstone	155	Groundwater flow from north through Taynton Limestone, Horsehay and Northampton Sand in this area is likely to be controlled by topography.
Highfurlong Brook (refer to Table 1)	Will be crossed by the Proposed Scheme.	Charmouth Mudstone Formation. (Unproductive strata).	Within valleys	Largely not in direct hydraulic connectivity with groundwater, although the river does receive flows from groundwater spring fed streams.

Location description (and map reference)	Distance (m) and direction from route	Formation	Approximate elevation (m AOD)	Comments
Oxford Canal Feeder (Lower Boddington). (refer to Table 1)	Will be crossed by the Proposed Scheme.	Charmouth Mudstone Formation. (Unproductive strata).	Within valleys	Largely not in direct hydraulic connectivity with groundwater, although the river does receive flows from groundwater spring fed streams.
River Cherwell (refer to Table 1)	Will be crossed by the Proposed Scheme.	Dyrham formation and Charmouth / Whitby Mudstone Formations. (mostly unproductive strata).	Within valleys	Largely not in direct hydraulic connectivity with groundwater, although the river does receive flows from groundwater spring fed streams. Some connectivity where the river lies above the Dyrham Formation (Secondary aquifer).
Three ponds north of Field Farm, Aston Le Walls. Three ponds north-west of Valley View Farm, Aston Le Walls.	Approximately 175m south-west of the Proposed Scheme. Approximately 205m north-east of the Proposed Scheme.	Dyrham Formation	130 – 135	Could be in connectivity with groundwater in the Dyrham Formation.
Pond close to Calves Close Spinney.	Approximately 215m north-east of the Proposed Scheme.	Dyrham Formation	128	Could be in connectivity with groundwater in the Dyrham Formation.

3.5 Water dependent habitats

3.5.1 Table 7 summarises the water dependent habitats within the study area. The table identifies where a water dependency exists. The assessment of residual impact or mitigation measures on water dependent ecology receptors is found in the Ecology section in Volume 2, CFA Report 15, Section 7. Map references are given for the Volume 5, Ecology Map Book.

Table 7: Description of water dependent habitats

Name / location	Distance	Designation	Comments
Trafford Bridge Marsh, approximately 1km east of Edgcote. (Map EC-01-037, C6)	Will be crossed by the Proposed Scheme.	LWS*	Meadowsweet fen community.
Culworth Marsh, approximately 600m west of Culworth village. (Map EC-01-036, C1)	Will be approximately 1km north-east from the Proposed Scheme.	LWS	Scrub. Open water.

Name / location	Distance	Designation	Comments
Washbrook Spinney, located in the valley between Stuchbury Manor Farm and Stuchbury Hall Farm. (Map EC-01-035, C3)	Will be approximately 700m north of the Proposed Scheme.	LWS	Woodland that may be supported by adjacent open water.
Washbrook Lake, located in the valley between Stuchbury Manor Farm and Stuchbury Hall Farm. (Map EC-01-035, C2 and D2)	Will be approximately 700m north of the Proposed Scheme.	LWS	Open water and grassland (marshy and lowland).
Costow fields, adjacent to Costow House approximately 500m east of Thorpe Mandeville. (Map EC-01-036, F7)	Will be crossed by the Proposed Scheme.	None	Area of habitat with fen characteristics
Woodland at Keepers Cottage, approximately 600m west of Greatworth. (Map EC-01-035, B10)	Will be approximately 1km south-west of the Proposed Scheme.	None	Woodland that may contain some areas of water dependant habitat
Woodland south-east of Greatworth. (Map EC-01-035, E10)	Will be approximately 1km south-west of the proposed scheme.	None	Woodland that may contain some areas of water dependant habitat
Ponds at Lower Thorpe. (Map EC-01-036, D6)	Will be on/adjacent to route.	Water dependant habitat	May support great crested newts.
Ponds at Aston le Walls, especially Manor Farm. (Map EC-01-038, D5)	Will be 280m north of the route.	Water dependant habitat	High species diversity for plants. May support great crested newts.
River Cherwell and tributaries (Map EC-01-037, D6)	Will be crossed by the route.	Biodiversity action plan (BAP) habitat.	Includes wetland / fen habitats.

* LWS: Local Wildlife Site (non statutory)

4 Site specific surface water assessment

4.1 Summary of assessment

4.1.1 Table 8 summarises the potential impacts and effects, both significant and not significant, to surface water features from the Proposed Scheme in the study area. Only those impacts and effects that are classed as significant are presented in Volume 2, CFA Report 15, Section 13.4.

4.1.2 Table 8 only includes water features which could potentially be impacted by the Proposed Scheme. Features such as isolated ponds and drains which will lie outside the construction footprint and area of impact of the Proposed Scheme are not included. Details of these features are, however, provided in Table 1. Map references refer to those presented on Maps WR-01-022 to WR-01-024 (Volume 5, Water Resources and Flood Risk Assessment Map Book).

4.1.3 The draft Code of Construction Practice (CoCP) referred to in Table 8 sets out the measures and standards of work that will be applied to the construction of the Proposed Scheme (see Volume 5: Appendix CT-003-000/1). These will provide effective management and control of the impacts during the construction period.

4.1.4 The proposed scheme has been designed to control impacts on the water environment during operation through drainage design incorporating sustainable drainage systems (SuDS) features and by following best practice pollution control guidance as agreed with the Environment Agency. As a result, there are no potentially significant impacts identified during the operation phase.

Table 8: Summary of potential impacts to surface water

Surface water feature/ receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact and effect	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Tributary of Radstone Brook	Moderate	Greatworth south cutting Land drainage area Drainage outfall	Permanent impact on flow regime in receiving watercourse.	Negligible impact Neutral effect (Not significant)	Balancing pond before outfall to watercourse to restrict runoff rates.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)
Unnamed Stream - Greatworth Fields	Moderate	Greatworth south cutting Land drainage area Drainage outfall	Land drainage upslope of cutting to be transferred via culvert to springhead. Permanent impact on flow regime in receiving watercourse.	Minor impact Slight effect (Not significant)	Three land drainage areas before outfall to watercourse to restrict runoff rates.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)
Unnamed Stream - Greatworth	Moderate	Greatworth south cutting Two land drainage areas One balancing pond for railway and access track drainage Drainage outfall	New drainage systems discharging to springhead. Permanent impact on flow regime in receiving watercourse. Deterioration in water quality from routine discharges from the railway and associated infrastructure or spills.	Minor impact Slight effect (Not significant)	Balancing pond before outfall to watercourse to restrict runoff rates and limit effect on water quality.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)

Surface water feature/ receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact and effect	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Five unnamed source streams of River Cherwell (SWC-CFA15-01 to SWC-CFA15-05)	High	Thorpe Mandeville embankment Lower Thorpe viaduct Two channel diversions and five culverts Balancing ponds Highway and rail drainage ditch Drainage outfall	During works for diversions and culverts and the balancing ponds and drainage, there is a potential for temporary impacts to flow. Potential sediment mobilisation or spills during construction.	Minor impact Moderate effect (Significant)	Measures to be adopted in the design process (see Section 4.2). CoCP measures to control sediment mobilisation and risk of spills. Pre- and post-construction monitoring.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (temporary)
Five unnamed source streams of River Cherwell (SWC-CFA15-01 to SWC-CFA15-05)	High	Balancing ponds Drainage outfall	Permanent impact on flow regime in receiving watercourse. Deterioration in water quality from routine discharges from the railway and associated infrastructure or spills.	Minor impact Moderate effect (Significant)	Balancing pond before outfall to watercourse to restrict runoff rates and limit effect on water quality.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)
Five unnamed source streams of River Cherwell (SWC-CFA15-03 and SWC-CFA15-04)	High	Lower Thorpe viaduct drainage	Direct drainage down viaduct piers See Section 4.2	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)

Surface water feature/ receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact and effect	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Six ponds adjacent to tributary of the River Cherwell (most are online to the watercourse)	High	Thorpe Mandeville embankment Lower Thorpe viaduct	Four ponds (SWC-CFA15-15 to SWC-CFA15-17 and SWC-CFA15-19) will be affected by the Proposed Scheme.	Moderate impact Moderate effect (Significant)	Drainage rearranged with additional wetland provided. Overall pond area will be similar.	Negligible impact Neutral effect (Not significant)	None	Neutral	Construction (Permanent)
Unnamed pond - Wadground Barn (SWC-CFA15-20)	Low	Culworth embankment	Pond will be lost. No significant effect on water resources	Negligible impact Neutral effect (Not significant)	Covered by land acquisition compensation.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)
Tributary of River Cherwell (Trafford Bridge) (SWC-CFA15-06)	Moderate	Balancing pond Drainage outfall	Permanent impact on flow regime in receiving watercourse. Deterioration in water quality from routine discharges from the railway and associated infrastructure or spills.	Minor impact Slight effect (Not significant)	Balancing pond before outfall to watercourse to restrict runoff rates and limit effect on water quality.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)

Surface water feature/ receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact and effect	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
River Cherwell (SWC-CFA15-07 and SWC-CFA15-21)	High	Lower Thorpe viaduct Channel diversions during viaduct construction	During works for the two diversions of the River Cherwell and the balancing ponds and drainage, there is a potential for temporary impacts to flow. Potential sediment mobilisation or spills during construction.	Minor impact Moderate effect (Significant)	Measures to be adopted in the design process (see Section 4.2). CoCP measures to control sediment mobilisation and risk of spills. Pre- and post-construction monitoring.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (temporary)
River Cherwell (SWC-CFA15-07 and SWC-CFA15-21)	High	Balancing pond Drainage outfall	Permanent impact on flow regime in receiving watercourse. Deterioration in water quality from routine discharges from the railway and associated infrastructure or spills.	Negligible impact Neutral effect (Significant)	Balancing pond before outfall to watercourse to restrict runoff rates and limit effect on water quality.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)
River Cherwell (SWC-CFA15-07 and SWC-CFA15-21)	High	Edgcote viaduct drainage	Direct drainage down viaduct piers See Section 4.2	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)

Surface water feature/ receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact and effect	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Tributary of River Cherwell (Welsh Road) (SWC-CFA15-08)	Moderate	New culvert	During works for the culvert on this River Cherwell tributary (Welsh Road) and the balancing ponds and drainage, there is a potential for temporary impacts to flow. Potential sediment mobilisation or spills during construction.	Minor impact Slight effect (Not significant)	Measures to be adopted in the design process (see Section 4.2). CoCP measures to control sediment mobilisation and risk of spills. Pre- and post-construction monitoring.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (temporary)
Tributary of River Cherwell (Welsh Road) (SWC-CFA15-08)	Moderate	Balancing ponds Drainage outfalls	Permanent impact on flow regime in receiving watercourse. Deterioration in water quality from routine discharges from the railway and associated infrastructure or spills.	Minor impact Slight effect (Not significant)	Balancing pond before outfall to watercourse to restrict runoff rates and limit effect on water quality.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)
Unnamed drain and 16 x Ponds at Aston Le Walls	Low	Route on embankment and viaduct	One pond will be lost entirely and three ponds partially lost	Major effect Moderate impact (Significant)	Lost pond area will be replaced within 300m.	Minor effect Neutral impact (Not significant)	None	Neutral	Construction (permanent)

Surface water feature/ receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact and effect	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Highfurlong Brook (SWC-CFA15-09) and pond on edge of flood plain (SWC-CFA15-25)	High	Channel diversion during viaduct construction Four balancing ponds Multiple drainage outfalls	During works for the diversion of the Highfurlong Brook and the balancing ponds and drainage, there is a potential for temporary impacts to flow. Potential sediment mobilisation or spills during construction.	Moderate impact Moderate effect (Significant)	Measures to be adopted in the design process (see Section 4.2). CoCP measures to control sediment mobilisation and risk of spills. Pre- and post-construction monitoring.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (temporary)
Highfurlong Brook (SWC-CFA15-09)	High	Four balancing ponds Multiple drainage outfalls	Permanent impact on flow regime in receiving watercourse. Deterioration in water quality from routine discharges from the railway and associated infrastructure or spills.	Moderate impact Moderate effect (Significant)	Balancing pond before outfall to watercourse to restrict runoff rates and limit effect on water quality.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)
Highfurlong Brook (SWC-CFA15-09)	High	Highfurlong Brook viaduct drainage	Direct drainage down viaduct piers See Section 4.2	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)

Surface water feature/ receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact and effect	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Unnamed Drain at Lower Boddington (SWC-CFA15-10)	Low	Inverted siphon/culvert	During works for the culvert on the drain at Lower Boddington and the balancing ponds and drainage, there is a potential for temporary impacts to flow. Potential sediment mobilisation or spills during construction.	Moderate impact Slight effect (Not significant)	Measures to be adopted in the design process (see Section 4.2). CoCP measures to control sediment mobilisation and risk of spills. Pre- and post-construction monitoring.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (temporary and permanent)
Unnamed Drain at Lower Boddington (SWC-CFA15-10)	Low	Balancing pond Rail drainage ditch and outfall	Permanent impact on flow regime in receiving watercourse. Deterioration in water quality from routine discharges from the railway and associated infrastructure or spills.	Moderate impact Slight effect (Not significant)	Balancing pond before outfall to watercourse to restrict runoff rates and limit effect on water quality.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)

Surface water feature/ receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact and effect	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Boddington Feeder (Oxford Canal) (SWC-CFA15-11)	High	Channel diversion, shortening of watercourse and culverting	During works for the channel diversion, shortening and culverting of the Boddington Feeder and the balancing ponds and drainage, there is a potential for temporary impacts to flow. Potential sediment mobilisation or spills during construction.	Moderate impact Moderate effect (Significant)	Measures to be adopted in the design process (see Section 4.2). CoCP measures to control sediment mobilisation and risk of spills. Pre- and post-construction monitoring.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (temporary)
Boddington Feeder (Oxford Canal) (SWC-CFA15-11)	High	Balancing Pond Rail Drainage ditch and outfall	Permanent impact on flow regime in receiving watercourse. Deterioration in water quality from routine discharges from the railway and associated infrastructure or spills.	Moderate impact Moderate effect (Significant)	Balancing pond before outfall to watercourse to restrict runoff rates and limit effect on water quality.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)

Surface water feature/ receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact and effect	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Unamed tributary of the Boddington Feeder (Oxford Canal). (SWC-CFA15-12)	Moderate	Channel diversion, shortening of watercourse and culverting	During works for the channel diversion, shortening and culverting of the Boddington Feeder and the balancing ponds and drainage, there is a potential for temporary impacts to flow. Potential sediment mobilisation or spills during construction.	Moderate impact Moderate effect (Significant)	Measures to be adopted in the design process (see Section 4.2). CoCP measures to control sediment mobilisation and risk of spills. Pre- and post-construction monitoring.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (temporary)
Unamed tributary of the Boddington Feeder (Oxford Canal). (SWC-CFA15-12)	Moderate	Balancing ponds Multiple drainage outfalls	Permanent impact on flow regime in receiving watercourse. Deterioration in water quality from routine discharges from the railway and associated infrastructure or spills.	Moderate impact Moderate effect (Significant)	Balancing pond before outfall to watercourse to restrict runoff rates and limit effect on water quality.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)

Surface water feature/ receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact and effect	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Unnamed tributary of the Boddington Feeder arising near Fox Covert(SWC-CFA15-13, SWC-CFA-26 and SWC-CFA-27, SWC-CFA15-29 and SWC-CFA15-30)	Moderate	New Culvert Drainage outfall	During works for the culvert on this watercourse and the balancing ponds and drainage, there is a potential for temporary impacts to flow. Potential sediment mobilisation or spills during construction.	Minor impact Neutral effect (Not significant)	Measures to be adopted in the design process (see Section 4.2). CoCP measures to control sediment mobilisation and risk of spills. Pre- and post-construction monitoring.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (temporary)
Unnamed tributary of the Boddington Feeder arising near Fox Covert(SWC-CFA15-13, SWC-CFA-26 and SWC-CFA-27, SWC-CFA15-29 and SWC-CFA15-30)	Moderate	Drainage outfall	Permanent impact on flow regime in receiving watercourse. Deterioration in water quality from routine discharges from the railway and roads and associated infrastructure or spills.	Moderate impact Slight effect (Not significant)	Balancing pond before outfall to watercourse to restrict runoff rates and limit effect on water quality.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)

4.2 Detailed assessments

Assessment of potential impacts on surface water crossings

4.2.1 The locations and descriptions of the surface water crossings in the Greatworth to Lower Boddington area are given in Table 9.

Table 9: Details of surface water crossings

Water feature	Crossing map reference (Maps WR-01-022 to WR-01-024)	Description	Culvert length[1] (m)	WFD water body, designation and status
Unnamed stream - Greatworth	Dry valley - no surface water feature crossed	Drop inlet culvert carrying land drainage from upslope of the Greatworth south cutting to the spring head of this stream	260	No status class shown in RBMP – assumed status Poor
River Cherwell headwater	SWC-CFA15-01	Drop inlet culvert passing beneath Thorpe Mandeville cutting	80	No status class shown in RBMP – assumed status Poor
River Cherwell headwater	SWC-CFA15-02	Lower Thorpe embankment, approximately 240m diversion and culvert	40	No status class shown in RBMP – assumed status Poor
River Cherwell headwater	SWC-CFA15-03	Lower Thorpe viaduct	Not applicable	No status class shown in RBMP – assumed status Poor
River Cherwell headwater	SWC-CFA15-04	Lower Thorpe viaduct	Not applicable	No status class shown in RBMP – assumed status Poor
Tributary of River Cherwell	SWC-CFA15-05	Culworth Grounds culvert	65	No status class shown in RBMP – assumed status Poor
Tributary of River Cherwell (Trafford Bridge)	SWC-CFA15-06	Edgcote viaduct and approximately 50m long realignment to avoid pier	Not applicable	No status class shown in RBMP – assumed status Poor
River Cherwell (near Trafford Bridge)	SWC-CFA15-07	Edgcote viaduct with approximately 80m long re-alignment of meander bend to avoid pier foundations	Not applicable	Cherwell (Ashby Brook to Cropredy) Poor
River Cherwell	SWC-CFA15-21	Edgcote viaduct 130m long diversion to avoid crossing	Not applicable	Cherwell (Ashby Brook to Cropredy) Poor
Tributary of River Cherwell (Welsh Road)	SWC-CFA15-08	Osierbed Spinney culvert under Edgcote north embankment	60	No status class shown in RBMP – assumed status Poor
Highfurlong Brook	SWC-CFA15-09	Highfurlong Brook viaduct and	Not applicable	Highfurlong Brook (Source to

Water feature	Crossing map reference (Maps WR-01-022 to WR-01-024)	Description	Culvert length[1] (m)	WFD water body, designation and status
		approximately 45m long realignment of channel to avoid viaduct pier		Wormleighton Brook) Good
Unnamed drain at Lower Boddington	SWC-CFA15-10	Lower Boddington inverted siphon	540	No status class shown in RBMP – assumed status Good
Boddington Feeder Channel	SWC-CFA15-11	Culvert	45 and 60	Boddington Feeder (Oxford Canal) Good
Tributary of the Boddington Feeder Channel	SWC-CFA15-12	Culvert	60	No status class shown in RBMP – assumed status Good
Unnamed tributary of the Boddington Feeder arising near Fox Covert	SWC-CFA15-27	Road realignment, new drainage and culvert	20	No status class shown in RBMP – assumed status Good
Unnamed tributary of the Boddington Feeder arising near Fox Covert	SWC-CFA15-28	Road realignment, new drainage and culvert	20	No status class shown in RBMP – assumed status Good
Unnamed tributary of the Boddington Feeder arising near Fox Covert	SWC-CFA15-30	Road realignment, new drainage and culvert	20	No status class shown in RBMP – assumed status Good
Unnamed tributary of the Boddington Feeder arising near Fox Covert	SWC-CFA15-31	Road realignment, new drainage and culvert	20	No status class shown in RBMP – assumed status Good
Unnamed tributary of the Boddington Feeder arising near Fox Covert	SWC-CFA15-13	Realignment and culvert	130	No status class shown in RBMP – assumed status Good

[1]The length is based on the consolidated construction boundary. The actual length of the culvert is to be confirmed and would be subject to agreement with the Environment Agency.

4.2.2 The crossings listed in Table 9 are locations where potential temporary or permanent impacts from construction have been identified. The approach will therefore be to minimise the impact on water quality, flow and drainage and thus minimise the impact on the ecology of the water features as well. The impacts on ecological receptors are addressed in the Ecology section, Volume 2, CFA Report 15, Section 7.

4.2.3 Construction of crossings will follow best practice as set out in the draft CoCP.

4.2.4 Two generic forms of construction will be considered if the culvert is on the line of the existing watercourse:

- construct a temporary watercourse diversion adjacent to the watercourse, build the new culvert, and then divert the watercourse through the new culvert; or
- by-pass the construction area by pumping water over the length required to build the online culvert.

4.2.5 The choice between which option to select will be taken on a location by location basis taking into account safety of the workforce, the volume of water, availability of land for the diversion, views of the Environment Agency and the programmed period to undertake the work.

4.2.6 Generally the Environment Agency will be consulted on the design of the culverts and diversion proposals and any other mitigation measures. Mitigation measures aligned with WFD objectives will include:

- avoiding culverts where possible and maintaining an open watercourse;
- minimising the culvert lengths as far as possible, even if this requires some realignment;
- maintaining the natural bed profile within the channel, both in terms of channel gradients and substrates;
- maintaining natural flow depths, widths and velocities, (including natural variance and diversity) at the culvert inlet and outlet;
- constructing diversions and realigned channel sections in advance to allow stabilisation and vegetation growth to minimise sediment mobilisation when the flow is first diverted; and
- other measures, to be agreed with the Environment Agency, to ensure that the culverts are environmentally sympathetic to minimise their impacts on natural processes and biodiversity as far as possible.

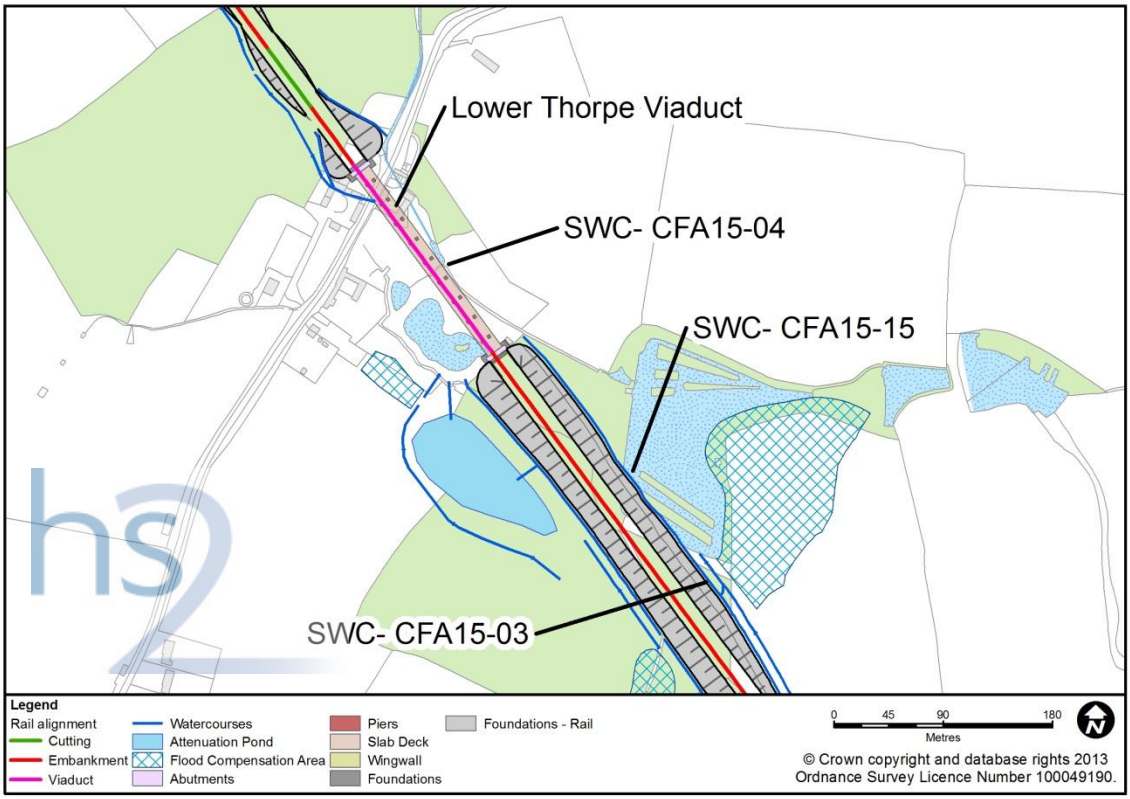
4.2.7 With the mitigation measures supported by pre- and post-construction monitoring and adherence to the requirements of the CoCP significant effects will be avoided.

Assessment of Lower Thorpe proposals (SWC-CFA15-03, SWC-CFA15-04 and ponds)

4.2.8 The Proposed Scheme will cross headwater tributaries of the River Cherwell at Lower Thorpe. The tributaries are connected to a series of large ponds prior to passing beneath Banbury Lane in an existing long culvert. In this area of complex channels and ponds it is proposed to construct the Lower Thorpe embankment and viaduct. The works are extensive and considerable modification of the channels is required to maintain hydraulic continuity downstream. The viaduct spans the existing flood plain and will not require changes to the main channel. The embankment will, however, result in the loss of a number of ponds.

4.2.9 Figure 2 shows the proposed arrangement for the channels and new drainage elements in the area to be occupied by the embankment.

Figure 2: Lower Thorpe viaduct - surface water crossings SWC-CFA15-03, SWC-CFA15-04 and SWC-CFA15-15



4.2.10 Two areas have been set aside for ecological mitigation measures – specifically wetland habitat creation. The details of these are given in Volume 2, CFA Report 15, Section 7. They are also shown on Map CT-06-072, Volume 2, CFA15 Map Book.

4.2.11 The design has incorporated a significant diversion of one tributary alongside the western foot of the embankment. The new channel will be constructed in advance and will be allowed to stabilise and vegetation to become established to control the risk of sediment mobilisation.

Assessment of the Edgcote viaduct (SWC-CFA15-06, SWC-CFA-07 and SWC-CFA15-21)

4.2.12 The route will cross the River Cherwell by the Edgcote viaduct at SWC-CFA15-07 and SWC-CFA15-21 and also a tributary at SWC-CFA15-06. The crossing locations are within the WFD water body Cherwell (Ashby Brook to Cropredy) which is designated as of overall Poor Status. The viaduct will span approximately 550m of the valley bottom.

4.2.13 At SWC-CFA15-06 and SWC-CFA15-07 short stretches of the channels will be permanently re-aligned/diverted beneath the viaduct to prevent the requirement for pier footings within the channels. As shown in Figure 3 the two realigned watercourses will pass beneath the viaduct between the proposed pier footing locations.

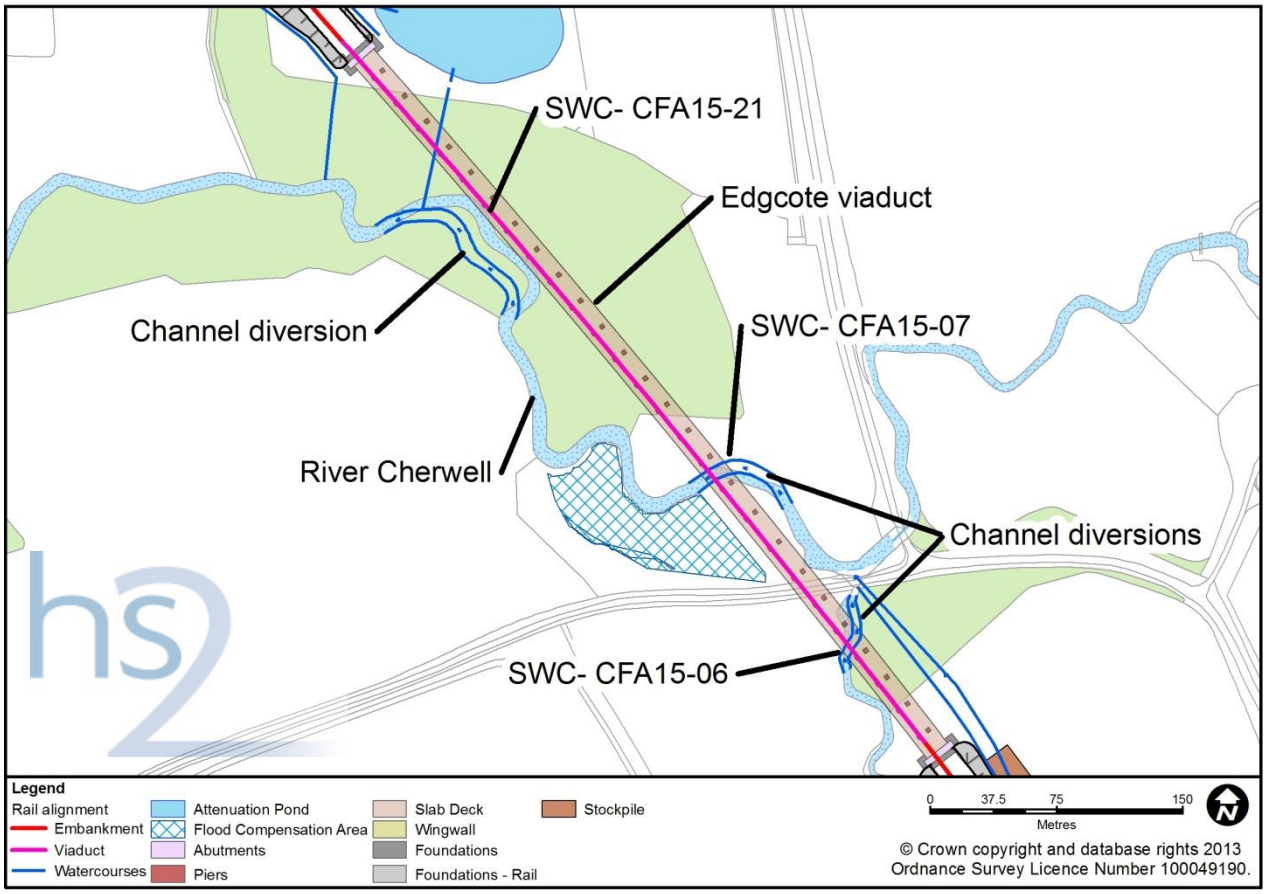
4.2.14 A further diversion is required of the River Cherwell at SWC-CFA15-21. The channel will be realigned approximately 15m south-west of its current route to prevent the requirement for pier footings adjacent to or within the channel. By diverting the

channel in this location the route will not require a further crossing of the River Cherwell.

4.2.15 The new diversion channels will be constructed in advance and will be allowed to stabilise and vegetation to become established to control the risk of sediment mobilisation when the river is actually diverted into the new channel section.

4.2.16 Overall the magnitude of the impacts on both flow and water quality in the watercourses affected are assessed as negligible. Consequently the significance of effects is assessed as neutral. No further mitigation is therefore required.

Figure 3: Edgcote viaduct - surface water crossings SWC-CFA15-06, SWC-CFA15-07 and SWC-CFA15-21



Assessment of the Highfurlong Brook viaduct and diversion (SWC-CFA15-09)

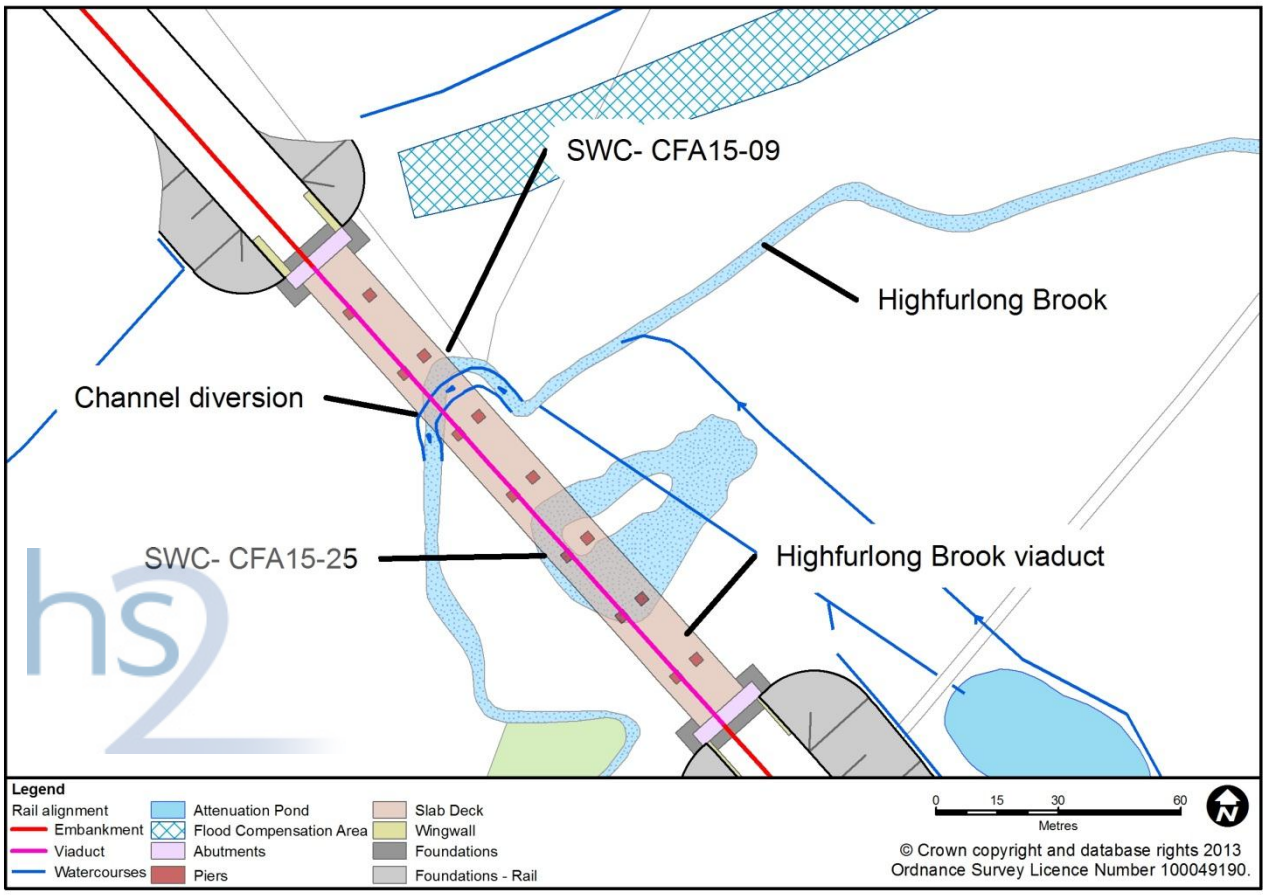
4.2.17 The route will cross the Highfurlong Brook at SWC-CFA15-09 by viaduct. A diversion channel, however, will be required to facilitate the placement of pier footings.

4.2.18 The channel is to be diverted between the pier footings to prevent construction of a pier footing immediately adjacent to the channel (Figure 4).

4.2.19 The short diversion will be designed to ensure that the existing flow and sediment regimes are maintained and acceptable to the Environment Agency. Due to the very small scale of the diversion the magnitude of the temporary and permanents impacts

from construction is considered to be negligible resulting in neutral effects which are not significant.

Figure 4: Highfurlong Brook viaduct and diversion - surface water crossings SWC-CFA15-09 and SWC-CFA15-25



Assessment of the Lower Boddington cutting inverted siphon (SWC-CFA15-10)

4.2.20 The route will cross an unnamed watercourse from the Boddington Feeder channel at SWC-CFA15-10 as part of the Lower Boddington cutting (Map WR-01-024; Volume 5, Water Resources and Flood Risk Assessment Map Book).

4.2.21 The route will be in a 620m cutting at this location and, due to topography, it is not possible for the watercourse to be culverted at the current watercourse bed level. An inverted siphon is therefore unavoidable, being the only technically viable option. The inverted siphon is proposed to carry the existing channel beneath the route and adjacent construction area.

4.2.22 The proposed inverted siphon for this crossing is for two pipes of 750mm diameter and 540m long.

4.2.23 The siphon has been designed to have sufficient capacity to pass the 100 year flow with an allowance for climate change.

4.2.24 To ensure hydraulic efficiency the siphon will be maintained to prevent blockage.

4.2.25 During construction the watercourse will require temporarily blocking and an over pumping system installed. The capacity of the pumped system will be equivalent to the existing drain and CoCP measures will be applied to ensure that the risk of sediment mobilisation and contamination from spills are acceptable.

4.2.26 The magnitude of temporary impact during construction will be minor as there will be no impact on the flows and water quality of the existing channel. The flow regime and sediment regime may be temporarily affected during the diversion of the existing culvert and the use of over-pumping to maintain the existing flow.

4.2.27 The value of the drain is considered to be moderate and therefore the significance of effect during construction is assessed as slight. The CoCP will address the risk of sediment mobilisation and contamination from accidental spills.

4.2.28 The magnitude of the impact for construction permanent is considered to be negligible. Therefore the significance of effect will be neutral.

Viaduct drainage

4.2.29 Surface water drainage from the three viaducts in the study area will be channelled down viaduct piers directly to the floodplain or watercourse below. The volume of storm runoff from these viaducts will be small in relation to flow in the receiving watercourse and will not have a significant effect on flow and there will be sufficient dilution to ensure no significant adverse effect on water quality. A route-wide assessment of drainage can be found in Volume 3, Route-wide effects.

Highway drainage

4.2.30 Highways works will include the temporary or permanent realignment of a number of minor roads and two larger roads as part of the Proposed Scheme in this area. Table 10 gives details of the proposals for highway works and the assumed receiving water body for new drainage discharge points. These have the potential to cause minor temporary and permanent impacts on water quality in receiving watercourses.

Table 10: Proposed highway works

Road	Proposals in current design	Assumed receiving surface water body
Helmdon Road near Greatworth	Temporary closure during construction of Greatworth green tunnel then permanent realignment 50m north of current alignment	Not applicable. Infiltration to ground.
B4525 near Greatworth	Temporary offline diversion during construction of Greatworth green tunnel then permanent reinstatement over the green tunnel	Not applicable. Infiltration to ground.
Sulgrave Road near Greatworth	Temporary offline diversion during construction of Greatworth green tunnel then permanent reinstatement over the green tunnel	Not applicable. Infiltration to ground.
Banbury Road at Thorpe Mandeville	Temporary diversion to the south during construction of the Thorpe Mandeville cutting then permanent realignment 30m to the north with new overbridge	Unnamed tributary of River Cherwell
A361 Byfield Road	Temporary offline diversion during construction of Chipping Warden green tunnel then	Not applicable. Infiltration to ground.

Road	Proposals in current design	Assumed receiving surface water body
	permanent reinstatement over the green tunnel	
Banbury Road near Upper Boddington	Realignment over 1km from near Spella Bungalow	Unnamed tributary of the Boddington Feeder and the unnamed tributary of the Boddington Feeder arising near Fox Covert
Stoneton Road towards Lower Boddington	Diversion to join Banbury Road	Unnamed tributary of the Boddington Feeder (Oxford Canal)
Claydon Road near Lower Boddington passing Three Shires Farm	Diversion to join re-aligned Banbury Road	Unnamed tributary of the Boddington Feeder arising near Fox Covert

4.2.31 The Scope and Methodology Report (SMR) (see Volume 5:Appendix CT-001-000/1) and the SMR Addendum (see Volume 5: Appendix CT-001-000/2) states that a Design Manual for Roads and Bridges[10] (DMRB) (Department for Transport, 2013) Highways Agency Water Risk Assessment Tool (HAWRAT) assessment is required for realigned roads forecast to exceed both an average annual daily traffic (AADT) value of 10,000 and a heavy goods vehicles (HGV) value of 500. The predicted AADT on all of these roads fall below the threshold for such detailed analysis.

4.2.32 Appropriate mitigation will be provided to address the risks to the receiving watercourses (for both flow and water quality) at the detailed design stage for the road re-alignments and will be selected using the DMRB (particularly HA103/06) and Construction Industry Research and Information Association (CIRIA) guidance[11]. The mitigation measures will be finalised at the detailed design stage. Remaining impacts will be negligible and the effect neutral as a result.

[10] http://www.dft.gov.uk/ha/standards/dmrb/vol11/section3/hd4509.pdf
[11] Murname, E., Heap, A. and Swain, A., 2006, C648 Control of Water Pollution from Linear Construction Sites, CIRIA, London, UK.

5 Site specific groundwater assessment

5.1 Summary of assessment

5.1.1 Table 11 summarises the potential impacts to hydrogeology (groundwater), abstractions, water dependent habitats and surface water/groundwater interactions. Only those impacts and effects that are classed as significant are presented in Volume 2, CFA Report 15, Section 13.4.

Table 11: Summary of potential impacts to groundwater receptors

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Hydrogeology (groundwater)									
Groundwater in the Northampton Sand Formation.	Moderate	Thorpe Mandeville cutting	This cutting will locally interfere with groundwater flows and create an isolated island of Northampton Sand. However, the proportion of this Secondary A aquifer that will be impacted is small. See Section 5.2 of this report for further details.	Minor impact Slight effect (Not significant)	None required	Minor impact Slight effect (Not significant)	None	None	Not applicable
Marlstone Rock Formation and Dyrham Formation Secondary aquifers.	Moderate	Edgcote cutting and Chipping Warden green tunnel	The cuttings will effectively create an isolated outcrop of Marlstone Rock and Dyrham Formation. This may cause localised drying of some areas of this outcrop. See Section 5.2 of this report for further details.	Minor impact Slight effect (Not significant)	None required	Minor impact Slight effect (Not significant)	None	None	Not applicable

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Abstractions									
Private abstraction (CFA15-GWUA03) will be approximately 400m to the north-east of the route at Stuchbury Manor Farm.	High	Greatworth south cutting	Water is collected from springs to the north and west by land drains before being pumped to the dairy and two properties. During construction the green tunnel will be open and will act as a groundwater sink drawing in water that would otherwise flow elsewhere. Once the green tunnel is complete it will no longer act as a groundwater sink. See Section 5.2 of this report for further details.	Moderate impact Moderate effect (Significant)	Where monitoring indicates that construction would impact on a groundwater source it will be necessary for an alternative water supply to be established prior to construction works.	Minor impact Slight effect (Not significant)	None required	Minor impact Slight effect (Not significant)	Construction (Permanent)
Private abstraction (CFA15-GWUA01), will be 250m to the north-east of the route at Bungalow Farm.	Low	Greatworth south cutting	The borehole at this location is disused.	Negligible impact Neutral effect (Not significant)	None required	Negligible impact Neutral effect (Not significant)	None	None	Not applicable
Abstractions within the Northampton Sand Formation (Licence No. 28/39/14/0298 and CFA15-GWUA04).	Moderate	Thorpe Mandeville cutting	These small abstractions will not be located in close proximity to, and will not have any hydraulic connection with, any cutting or tunnelling activities. See Section 5.2 of this report for further details.	Negligible impact Neutral effect (Not significant)	None required	Negligible impact Neutral effect (Not significant)	None	None	Not applicable

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
There are records of four licenced abstraction locations (28/39/14/0177) at Appletree Farm but only one borehole is in use. This will be located approximately 750m from the proposed scheme, to the east of Hilltop Cottage.	Moderate	Chipping Warden green tunnel. Edgcote cutting.	Abstraction is from the Dyrham Formation which is fully penetrated by this borehole. Groundwater flow is likely to be parallel to the route in this area. Both the green tunnel and cutting will act as groundwater sinks during the construction phase and may reduce water levels and yield in this borehole. Once construction of the green tunnel is complete it will no longer act as a groundwater sink and the impact on this abstraction will be reduced. See Section 5.2 of this report for further details.	Moderate impact Moderate effect (Significant)	Where pre-construction monitoring indicates that construction would impact on a groundwater source it will be necessary for mitigation measures to be agreed with licence holder (See Section 5.2 for further details) prior to construction works.	Negligible impact Neutral effect (Not significant)	None required	Negligible impact Neutral effect (Not significant)	Construction (Temporary)
Surface water / groundwater interaction									
Spring 450m south of Halse Copse South and will be approximately 130m south-west of the route.	Moderate	Greatworth south cutting	SP 1 in Figure 6. See Section 5.2 of this report for further details.	Minor impact Slight effect (Not significant)	Track and land drainage will be discharged to this minor watercourse.	Negligible impact Neutral effect (Not significant)	None	None	Not applicable

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Spring south-east of Halse Copse Farm, will be approximately 670m south of the route.	Moderate	Greatworth south cutting	SP 2 in Figure 6 SP 3 is also in this area See Section 5.2 of this report for further details.	Negligible impact Neutral effect (Not significant)	Not required	Negligible impact Neutral effect (Not significant)	None	None	Not applicable
Spring at Bungalow Farm, will be approximately 550m north-east of the route.	Moderate	Greatworth south cutting	SP 5 in Figure 6 See Section 5.2 of this report for further details.	Negligible impact Neutral effect (Not significant)	Not required	Negligible impact Neutral effect (Not significant)	None	None	Not applicable
Spring south-east of Greatworth Fields, will be approximately 300m south-west of the route.	Moderate	Greatworth south cutting	SP 4 in Figure 6 See Section 5.2 of this report for further details.	Minor impact Slight effect (Not significant)	Surface drainage from the north-eastern side of the cutting will be directed to the minor watercourse south-east of Greatworth Fields. This will mitigate any impact on this spring.	Negligible impact Neutral effect (Not significant)	None	None	Not applicable

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Issues and minor watercourse south-west of Greatworth Hall, will be approximately 150m south-west of the route.	Moderate	Greatworth north cutting Greatworth green tunnel.	SP 7 in Figure 8 See Section 5.2 of this report for further details.	Moderate impact Moderate effect (Significant)	Track and land drainage will be discharged to the spring fed stream at Greatworth Hall via a balancing pond. This will ensure that there is a negligible impact on this watercourse as much of the groundwater intercepted by the track drainage will be discharged to this watercourse.	Negligible impact Neutral effect (Not significant)	None required.	Negligible impact Neutral effect (Not significant)	Construction (Permanent)
Issues south of Floyds Farm, will be approximately 800m south-west of the route.	Moderate	Greatworth green tunnel.	See Section 5.2 of this report for further details.	Minor impact Slight effect (Not significant)	None required	Minor impact Slight effect (Not significant)	None	None	Not applicable
Issues at Oldbarn Spinney, will be approximately 640m south-west of the route.	Moderate	Greatworth green tunnel.	See Section 5.2 of this report for further details. Following construction of the green tunnel groundwater levels will recover and flow to the springs should be re-established.	Minor impact Slight effect (Not significant)	Minor impact Slight effect (Not significant)	Minor impact Slight effect (Not significant)	None required	Minor impact Slight effect (Not significant)	Construction (Temporary)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Spring at Painters Spinney, will be approximately 220m north-east of the route.	Moderate	Greatworth green tunnel.	See Section 5.2 of this report for further details. Following construction of the green tunnel groundwater levels will recover and flow to the springs should be re-established.	Moderate impact Moderate effect (Significant)	No practical mitigation measures can be implemented.	Moderate impact Moderate effect (Significant)	No practical mitigation measures can be implemented.	Moderate impact Moderate effect (Significant)	Construction (Temporary)
Issues at Keepers Cottage, will be approximately 900m south-west of the route.	Moderate	Greatworth green tunnel.	See Section 5.2 of this report for further details	Minor impact Slight effect (Not significant)	None required	Minor impact Slight effect (Not significant)	None	None	Not applicable
Springs and issues at Marston Hill Farm, will be approximately 950m south-west of the route.	Moderate	Greatworth green tunnel.	See Section 5.2 of this report for further details	Minor impact Slight effect (Not significant)	None required	Minor impact Slight effect (Not significant)	None	None	Not applicable
Springs and issues south-east of Thorpe Mandeville, south of Costow House, will be approximately 840m south-west of the route.	Moderate	Greatworth green tunnel.	See Section 5.2 of this report for further details	Minor impact Slight effect (Not significant)	None required	Minor impact Slight effect (Not significant)	None	None	Not applicable

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
One Issue and two springs in the upper reaches of a tributary of the River Cherwell which rises east and south of Costow House, Thorpe Mandeville.	Moderate	Thorpe Mandeville cutting.	See Section 5.2 of this report for further details. One issue will be permanently lost (SWC-CFA15-01) and reduction in flow to the other two nearby springs.	Moderate impact Moderate effect (Significant)	The scheme design incorporates returning any groundwater intercepted by the Thorpe Mandeville cutting to upper reaches of the Culworth Brook north-east of Thorpe Mandeville. However it is anticipated there will still be a reduction of baseflow to the upper 800m of this watercourse, which may have an impact to the potential water dependent habitat.	Moderate impact Moderate effect (Significant)	No further practical mitigation measures can be implemented.	Moderate impact Moderate effect (Significant)	Construction (Permanent)
Issues and minor watercourse south-west of Magpie Farm and will be approximately 250m north-east of the route.	Moderate	Thorpe Mandeville cutting.	See Section 5.2 of this report for further details	Minor impact Slight effect (Not significant)	None required	Minor impact Slight effect (Not significant)	None	None	Not applicable

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
One very small spring 100m from the route and two springs very close to the river channel in the River Cherwell valley north and east of Edgcote within 500m of the cutting. Two springs over 800m from the cutting on south side of Chipping Warden.	Low (a small spring) Others are Moderate	Edgcote cutting.	Potential reduction in groundwater flow to the springs. See Section 5.2 of this report for further details	Moderate impact on low value spring Slight effect Minor impact on other springs Slight effect (Not significant)	Cutting drainage will discharge into the river near the route crossing and close to the small low value spring. This will maintain flow to the river valley.	Moderate impact on low value spring Slight effect Minor impact on other springs Slight effect (Not significant)	None	Moderate impact on low value spring Slight effect Minor impact on other springs Slight effect (Not significant)	Construction (permanent)
Minor seepages and springs west of Aston Le Walls (high value - Highfurlong Brook) no closer than 400m from the route.	Moderate	Chipping Warden green tunnel.	See Section 5.2 of this report for further details	Minor impact Slight effect (Not significant)	None required	Minor impact Slight effect (Not significant)	None	None	Not applicable
Spring approximately 400m west of Valley View Farm, will be very close to the northern side of the tunnel portal.	Low	Chipping Warden green tunnel.	Spring does not appear to contribute to other surface water features See Section 5.2 of this report for further details	Moderate impact Slight effect (Not significant)	Drainage will capture water from a wider area, pass near the spring and discharge to the Highfurlong Brook.	Moderate impact Slight effect (Not significant)	None required	None	Construction (Permanent)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Springs feeding several minor watercourses on south east side of Chipping Warden	Moderate	Chipping Warden Green tunnel	Groundwater flow could be diverted in the Dyrham Formation that would flow towards these springs. Once the green tunnel is completed groundwater flow would revert to normal conditions.	Moderate impact Moderate effect (Significant)	No practicable mitigation measures can be implemented during construction.	Moderate impact Moderate effect (Significant)	No practicable measures possible	Moderate impact Moderate effect (Significant)	Construction (Temporary)
Minor water course and pond close to Calves Close Spinney.	Moderate (Watercourse) Low (Pond)	Chipping Warden green tunnel.	There could be some reduction in groundwater flow to these features as a result of construction of the green tunnel. However, it is likely the pond is self sealed. Once the tunnel is completed there will be no significant adverse effect to these features. See Section 5.2 of this report for further details.	Minor impact on watercourse. Minor impact on pond Slight effect on watercourse Neutral effect on pond (Not significant)	No practical mitigation measures can be implemented.	Minor impact Slight effect (Not significant)	None required	None	Construction (temporary)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Three ponds north of Field Farm, Aston Le Walls. Three ponds north of Valley View Farm, Aston Le Walls.	Low	Chipping Warden green tunnel.	There could be some reduction in groundwater flow to these ponds as a result of construction of the green tunnel. Once the tunnel is completed there will be no significant adverse effect to these ponds. See Section 5.2 of this report for further details.	Moderate impact Slight effect (Not significant)	No practical mitigation measures can be implemented.	Moderate impact Slight effect (Not significant)	None required	None	Construction (temporary)
Water Dependent Habitats									
Trafford Bridge Marsh, approximately 1km east of Edgcote. (Map EC-01-037, C6)	Moderate	Edgcote viaduct.	During works for the two diversions of the River Cherwell and the balancing ponds and drainage, there is a potential for temporary impacts to flow, although the measures presented in the CoCP and adopted in the design process will ensure there is an insignificant effect. (Refer to Table 8 of this report)	Minor impact Moderate effect (Significant)	Measures to be adopted in the design process (see Section 4.2). CoCP measures to control sediment mobilisation and risk of spills. Pre- and post-construction monitoring.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)
Culworth Marsh, approximately 600m west of Culworth village. (Map EC-01-036, C1)	Moderate	Culworth embankment.	The embankment is unlikely to adversely affect any groundwater or surface water flow contributing to the marsh.	Negligible impact Neutral effect (Not significant)	Not required	Negligible impact Neutral effect (Not significant)	None	None	Not applicable

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Washbrook Spinney, located in the valley between Stuchbury Manor Farm and Stuchbury Hall Farm. (Map EC-01-035, C3)	Moderate	Greatworth green tunnel.	Although there could be some reduction in flow to the LWS as a result of the cutting, there position of the LWS in the valley ensures that there will continue to be flow from the north that is not intercepted by the cutting.	Minor impact Slight effect (Not significant)	None required	Minor impact Slight effect (Not significant)	None	Minor impact Slight effect (Not significant)	Construction (temporary)
Washbrook Lake, located in the valley between Stuchbury Manor Farm and Stuchbury Hall Farm. (Map EC-01-035, C2 and D2)	Moderate	Greatworth green tunnel.	Although there could be some reduction in flow to the LWS as a result of the cutting, there position of the LWS in the valley ensures that there will continue to be flow from the north that is not intercepted by the cutting.	Minor impact Slight effect (Not significant)	None required	Minor impact Slight effect (Not significant)	None	Minor impact Slight effect (Not significant)	Construction (temporary)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Costow fields, adjacent to Costow House approximately 500m east of Thorpe Mandeville. (Map EC-01-036, F7)	Moderate	Thorpe Mandeville cutting	The Costow Fields lie above the Whitby Mudstone Formation which is unproductive strata. These habitat is not, therefore, groundwater dependent. The fields do, however, run adjacent to the stream fed by a spring/issue east of Costow House. This issue may be affected by the cutting. See Section 5.2 of this report for further details.	Moderate impact Moderate effect (Significant)	The scheme design incorporates returning any groundwater intercepted by the Thorpe Mandeville cutting to upper reaches of the Culworth Brook north-east of Thorpe Mandeville. However it is anticipated there will still be a reduction of baseflow to the upper 800m of this watercourse, which may have an impact to the potential water dependent habitat.	Moderate impact Moderate effect (Significant)	No further practical mitigation measures can be implemented.	Moderate impact Moderate effect (Significant)	Construction (Permanent)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Woodland at Keepers Cottage, approximately 600m west of Greatworth. (Map EC-01-035, B10)	Low	Greatworth green tunnel	The woodland is surrounded by small streams fed by the springs and issues that emerge at Keepers Cottage. The woodland itself lies above the Whitby Mudstone Formation and is not, therefore, in direct connectivity with groundwater. The springs/issues at Keepers Cottage are unlikely to be significantly affected by the tunnel. See Section 5.2 of this report for further details.	Minor impact Slight effect (Not significant)	None required	Minor impact Slight effect (Not significant)	None	Minor impact Slight effect (Not significant)	Construction (temporary)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Woodland south-east of Greatworth. (Map EC-01-035, E10)	Low	Greatworth green tunnel	The woodland is surrounded by small streams fed by the springs and issues that emerge at Keepers Cottage. The woodland itself lies above the Whitby Mudstone Formation and is not, therefore, in direct connectivity with groundwater. A spring fed stream flows around the boundary of the woodland. The springs/issues are unlikely to be significantly affected by the tunnel. See Section 5.2 of this report for further details.	Minor impact Slight effect (Not significant)	None required	Minor impact Slight effect (Not significant)	None	Minor impact Slight effect (Not significant)	Construction (temporary)
Ponds at Lower Thorpe. (Map EC-01-036, D6)	Low	Thorpe Mandeville embankment and Lower Thorpe viaduct.	Four ponds (SWC-CFA15-15 to SWC-CFA15-17 and SWC-CFA15-19) will be affected by the Proposed Scheme. (refer to Table 8 of this report)	Moderate Impact Moderate Effect (Significant)	Drainage rearranged with additional wetland provided. Overall pond area will be similar.	Negligible Impact Neutral Effect (Not significant)	None	Neutral	Construction (Permanent)
Ponds at Aston le Walls, especially Manor Farm. (Map EC-01-038, D5)	Low	Aston Le Walls embankment	One pond will be lost entirely and three ponds partially lost. (refer to Table 8 of this report)	Major effect Moderate impact (Significant)	Lost pond area are will be replaced within 300m.	Minor Effect Neutral Impact (Not significant)	None	Neutral	Construction (permanent)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
River Cherwell and tributaries (Map EC-01-037, D6)	High	Edgcote viaduct.	During works for the two diversions of the River Cherwell and the balancing ponds and drainage, there is a potential for temporary impacts to flow and quality. (Refer to Table 8 of this report)	Minor impact Moderate effect (Significant)	Measures to be adopted in the design process (see Section 4.2). CoCP measures to control sediment mobilisation and risk of spills. Pre- and post-construction monitoring	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (temporary)

5.2 Detailed assessments

Assessment of cuttings and green tunnels

Calculation of zone of influence

5.2.1 In order to establish the extent to which dewatering may cause drawdown and affect the groundwater flow regime Sichardt's formula has been used to predict drawdowns following guidance in the Construction Industry Research and Information Association (CIRIA) C515 (2000) Groundwater control – design and practice[12] and CIRIA C113 (1986) Control of groundwater for temporary works[13]. Sichardt's formula is presented below:

$$Lo = C \times h \times Sk$$

Where; Lo = distance of influence from linear structure (m)

k = hydraulic conductivity (m/s)

h = drawdown (m)

C = empirical factor taken to be 2000

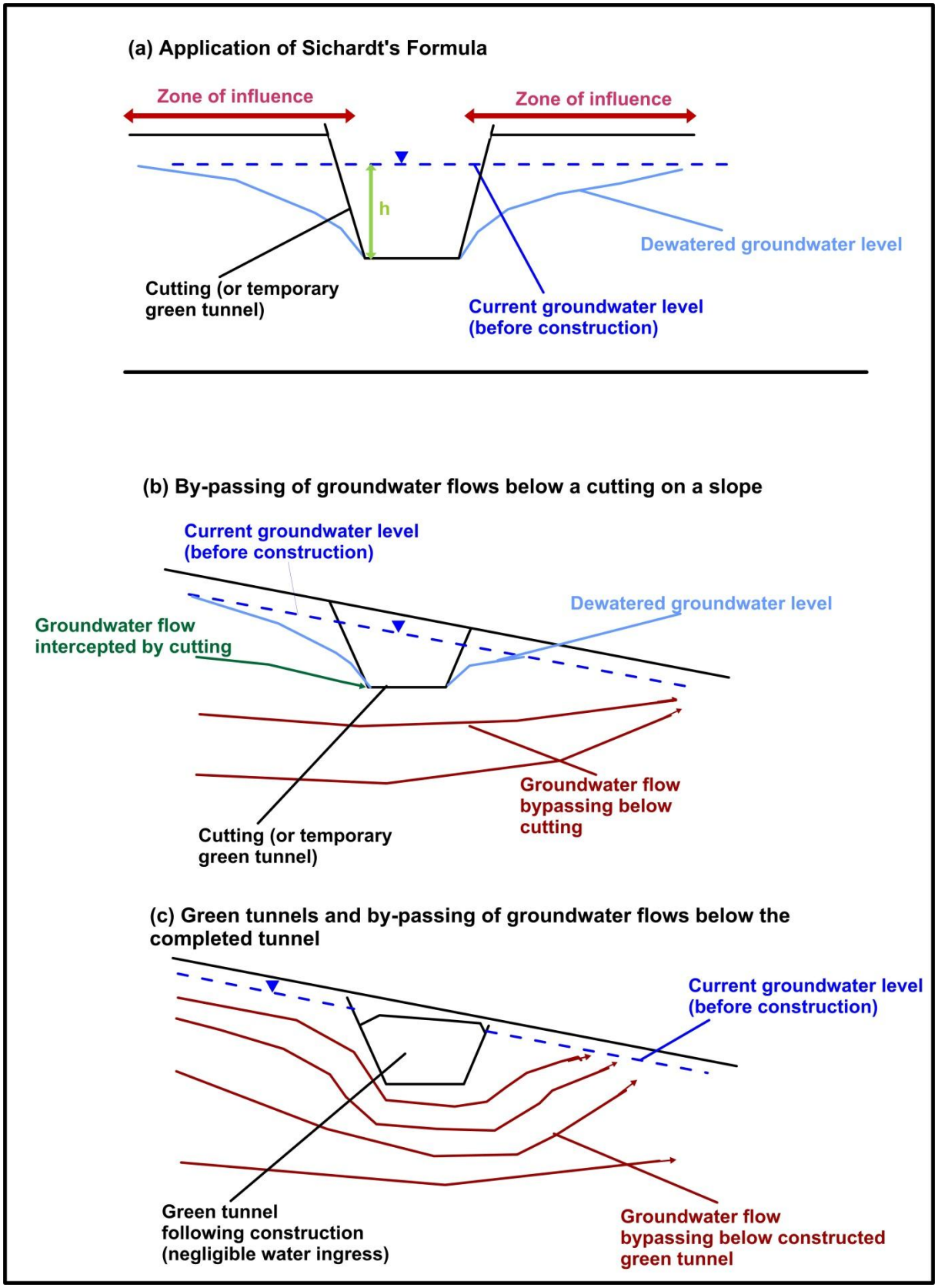
5.2.2 For the green tunnel (where the tunnel is below the groundwater level) and the cutting k is taken to be the 75th percentile taken from BGS (1997)[9], where available, and h from the maximum groundwater elevation to the base of the cutting. Where the base of the scheme is close to or at the inferred groundwater table any dewatering will be minimal with the zone of influence being at the route. Where the base of the scheme is at the maximum depth below the water table the extent of dewatering will be furthest from the route.

5.2.3 Figure 5 illustrates schematically how Sichardt's formula has been applied and how a completed cutting and green tunnel will affect the groundwater flow regime:

- panel (a) shows the drawdown around a cutting in an aquifer with a horizontal water table;
- panel (b) shows how in an area of flowing groundwater, some flow will bypass a cutting even though this is acting as a drain; and
- panel (c) shows how flows will redistribute around a green tunnel in the operational, permanent case once it is sealed.

[12] CIRIA, 2000, *CIRIA C515 Groundwater control – design and practice*
[13] CIRIA, 1986, CIRIA C113 Control of groundwater for temporary works

Figure 5: Schematic representation of dewatering, groundwater flows and zone of influence



5.2.4 Table 12 summarises the cuttings and green tunnels in CFA15. Those cuttings identified as requiring mitigation are discussed in more detail after Table 12.

Table 12: Summary of cuttings and green tunnels in the study area

Cutting name	Geology penetrated	Groundwater elevation	Effect on groundwater resources	Mitigation
Greatworth south cutting	Till (Unproductive) Glaciofluvial deposits (Secondary A aquifer) Great Oolite Group (Principal aquifers) Inferior Oolite at the northern edge of the cutting (Secondary A aquifer)	No monitoring data available, inferred to be at or slightly below the cutting based on spring elevations and topography	The cutting could intercept some groundwater in the Great Oolite, affecting spring flows and spring fed streams. Any shallow groundwater in the Glaciofluvial deposits would be intercepted. See Greatworth south cutting section for further details.	Track drainage to local watercourses will minimise impacts on flow at some of these receptors. No other practicable mitigation possible.
Greatworth north cutting	Great Oolite (Secondary aquifers) Inferior Oolite (Secondary A aquifer) Whitby Mudstone (Unproductive)	Inferred to be at or below the cutting	Owing to the depth of the water table relative to the cutting there will be not substantial changes to the groundwater flow regime, although there could be a minor impact to the spring fed stream at Greatworth Hall. See Greatworth north cutting section for further details.	Track and land drainage to spring fed stream at Greatworth Hall will ensure this watercourse is not significantly effected.
Greatworth green tunnel	Great Oolite (Secondary aquifers) Inferior Oolite (Secondary A aquifer) Whitby Mudstone (Unproductive)	Water table above the tunnel	Potential to affect flow to seven springs and a private abstraction. See Greatworth green tunnel section for further details.	Track and land drainage to spring fed stream at Greatworth Hall will ensure this watercourse is not significantly effected.
Thorpe Mandeville cutting	Great Oolite (Secondary aquifers) Inferior Oolite (Secondary A aquifer) Whitby Mudstone (Unproductive)	Water table above the cutting	Potential to affect flow to a number of springs and loss of one issue east of Costow House (SWC-CFA15-01). See Thorpe Mandeville cutting section for further details.	Track and land drainage to spring fed stream at Greatworth Hall will ensure this watercourse is not significantly effected. Monitoring of surface water flows and groundwater levels one or two years prior to and during construction could be carried out to determine the potential impact of construction on the aquifer, spring flows and local abstractions.

Cutting name	Geology penetrated	Groundwater elevation	Effect on groundwater resources	Mitigation
Lower Thorpe cutting south	Whitby Mudstone (Unproductive)	Unproductive strata	No groundwater present.	Not required
Lower Thorpe cutting north	Whitby Mudstone (Unproductive)	Unproductive strata	No groundwater present.	Not required
Culworth cutting	Whitby Mudstone (Unproductive)	Unproductive strata	No groundwater present.	Not required
Edgcote cutting	Marlstone Rock and Dyrham Formation (Secondary aquifers)	Water table considered to be above the cutting	Groundwater flow to three springs that contribute to stream flows towards the River Cherwell could be affected. See Edgcote cutting section for further details.	Track drainage will be discharged to the River Cherwell and some of its tributaries via balancing ponds.
Chipping Warden green tunnel	Whitby Mudstone Formation (Unproductive) Marlstone Rock Formation (Secondary aquifer) Dyrham Formation (Secondary aquifer)	Water table above tunnel for part of the route	Potential impact to groundwater flow to springs and four abstractions near Appletree Farm. See Chipping Warden green tunnel section for further details.	Monitoring at abstractions.
Aston Le Walls cutting	Dyrham and Charmouth Formation	Unproductive strata	No groundwater present.	Not required
Lower Boddington cutting	Dyrham and Charmouth Formation	Unproductive strata	No groundwater present.	Not required

Greatworth south cutting

5.2.5 A summary of the cutting details are provided in Table 13.

Table 13: Summary of Greatworth south cutting detailed groundwater assessment

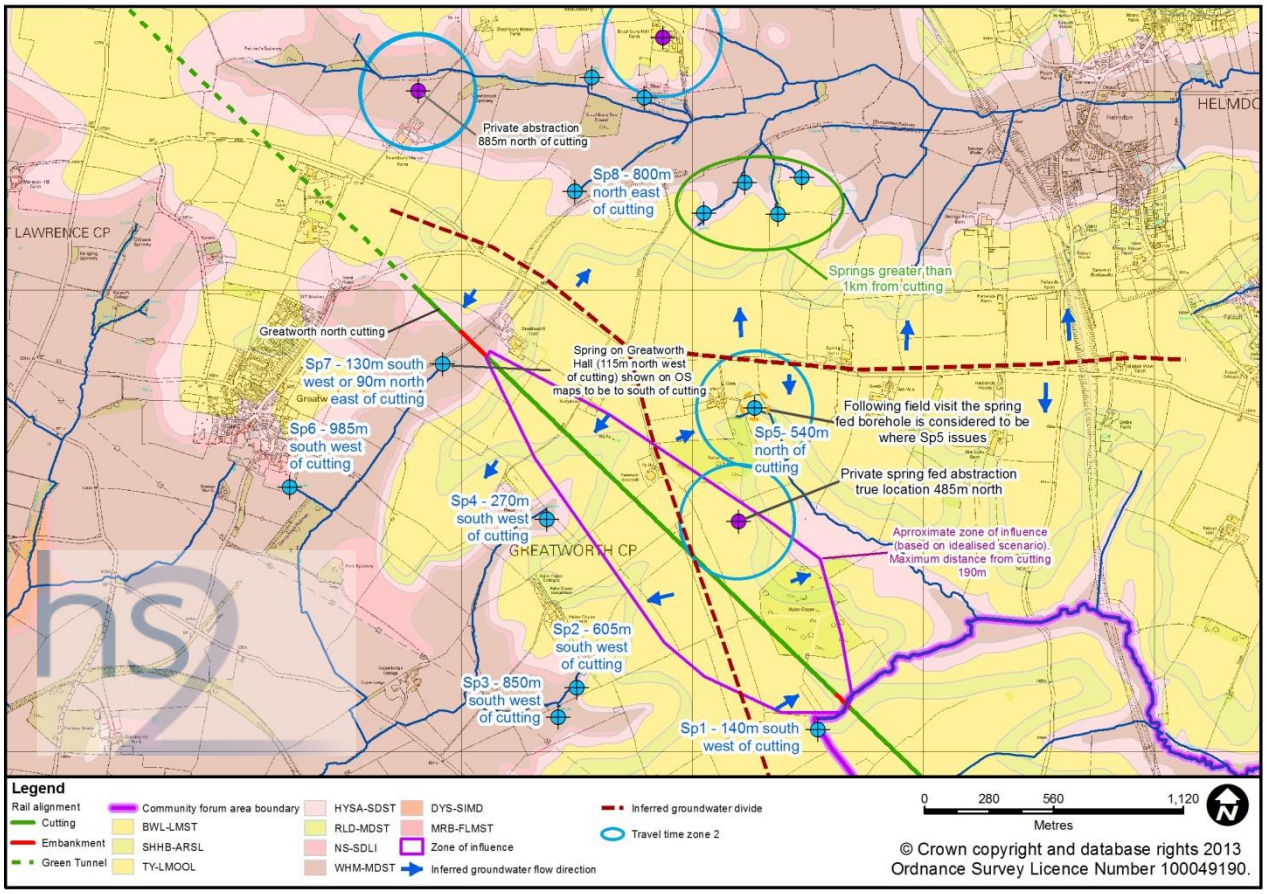
Cutting parameters	Parameter details
Length (km)	2.05
Maximum depth (m)	10
Strata Intercepted	Till (unproductive) Glaciofluvial sands and gravels (Secondary A aquifer) Great Oolite, comprising Blisworth Limestone, Rutland Mudstone, Taynton Limestone, Horeshay Sand Formation); Principal and Secondary aquifers Inferior Oolite (Northampton Sand Formation), Secondary A aquifer
Lowest track level (m AOD)	151.0

Groundwater level(s) (m AOD)	Water table in the bedrock inferred to be at approximately the cutting depth (based on topography and spring elevations). Design Element Statement indicates water table to be between 140 and 160m AOD Water table in the superficial deposits considered to be close to surface
Principal receptors (see Figure 6)	Groundwater (Great and Inferior Oolite aquifers) Springs; Sp1 - 140m south-west of route, near boundary with CFA14 Sp2 - 605m south-west of route, south of Halse copse Farm Sp3 - 850m south-west of route, south of Halse copse Farm Sp4 - 270m south-west of route at Greatworth Fields Sp5 - 540m north-east of route, just north of Halse Copse Sp6 - 985m south-west of route, south of Greatworth Sp7 - 130m south-west of route, south of Greatworth Hall Sp8 – 800m north-east of route at Stuchbury Fox covert One unlicensed abstraction 215m north-east of route, south of Bungalow Farm

5.2.6 The Greatworth south cutting will pass principally through the Great Oolite which comprises a number of formations (Blisworth Limestone, Rutland Mudstone, Taynton Limestone and Horsehay Sand) with the Inferior Oolite lying beneath (Northampton Sand Formation). These are a mixture of Principal and Secondary aquifers that overly the Whitby Mudstone (Unproductive Strata). Along almost the entire length of the proposed cutting superficial Till deposits overly the Glaciofluvial deposits (Secondary aquifer). The Glaciofluvial deposits and underlying Great and Inferior Oolites are considered to be in hydraulic connectivity.

5.2.7 There are a number of springs within the vicinity of the proposed cutting as shown on Figure 6. These springs largely issue at the contact between the Northampton Sand Formation (or Horsehay Sand Formation where the Northampton Sand is absent) and the underlying Whitby Mudstone. There is a private unlicensed abstraction located 215m north-east of the route near Bungalow Farm which is likely to abstract from the Great Oolite Group. Following a field visit this spring fed abstraction was identified to be approximately 485m further north than records indicate (it is located at Sp5 as shown in Figure 6); as such the calculated zone two time of travel will not be intercepted by the cutting.

Figure 6: Location of geology and springs within the vicinity of the Greatworth south cutting[14]



5.2.8 The water table is likely to be between 140 and 160m AOD and can be inferred from the spring elevations, topography and surface watercourses in the area. The groundwater table is likely to be, at it's maximum, close to the cutting depth as shown in Figure 7. However, it is also likely that the main groundwater table is lower than the cutting within the Great Oolite. The highest elevation issues/springs are discharging from areas where the surface deposits are Till. Therefore these are most likely due to higher permeability layers in the Till discharging, rather than the Great Oolite formations discharging through the Till. The majority of the springs around the cutting are at lower elevations (as shown in Figure 7) and discharge from the lowermost Great Oolite Horsehay Sand Formation or even the underlying Whitby Mudstone. This indicates that the regional water table is not likely to be very elevated in the overlying formations of the Great Oolite Group. Only during periods of high rainfall is it likely that the water table may be above the base of the cutting.

5.2.9 As the Glaciofluvial deposits and Great Oolite are expected to be in hydraulic connectivity it is unlikely that there will be substantial quantities of groundwater in the Glaciofluvial deposits within the vicinity of the proposed cutting as they will drain into the underlying formations.

[14] Key to geology legend: BWL-LMST = Blisworth Limestone Formation, SHHB-ARSL = Sharp's Hill Formation, TY-LMOOL = Taynton Limestone Formation, HYSA-SDST = Horsehay Sand Formation, RLD-MDST = Rutland Formation - Mudstone, NS-SDLI = Northampton Sand Formation, WHM-MDST = Whitby Mudstone Formation, DYS-SIMD = Dyrham Formation and MRB-FLMST = Marlstone Rock Formation.

5.2.10 Assuming the local groundwater mirrors the surface topography there appear to be potentially two groundwater divides within the vicinity of the proposed cutting. One divide runs west/east and will be to the east of the very northern part of the cutting and the other divide runs south-east and will be intercepted by the route in the centre of the cutting, as shown in Figure 6. Groundwater flow in the northern 1.25km of the cutting will therefore largely be to the west and south-west and flow in the southern 800m will be to the east and north-east - ie. it will flow towards the river valleys around the cutting.

5.2.11 At the south of the cutting the thickness of the Great/Inferior Oolite is approximately 21m, gradually decreasing northwards to approximately 1 or 2m at Greatworth. As a result, any interference of groundwater flow caused by the cutting will be less pronounced in the south where there will be greater flow below the cutting. In the north the cutting could interfere with more of the groundwater as the aquifer becomes thinner.

5.2.12 During dry periods when the groundwater elevation is relatively low any interference of the groundwater caused by the cutting will be negligible as the water table is likely to be at or below the cutting. During periods of higher groundwater elevations, i.e. following significant rainfall, there will be a larger volume of water intercepted by the cutting. Any potential impact, however, on the wider groundwater flow during these periods will be counterbalanced by the greater volume of water present in the catchment overall.

5.2.13 Using Sichardt's principles the approximate extent of impact of the cutting can be estimated, which is shown on Figure 6. The zone is based, however, on maximum possible drawdown due to the groundwater table being at a maximum elevation of 160m AOD. In reality the zone of influence will be skewed to account for the different flow directions (either side of the groundwater divide) and topography. As such, the zone should only be referred to as indicative and conservative in its extent. None of the key receptors fall within the zone of influence, including the true location of the private abstraction so none will be directly lost. There may, however, be some reduction in groundwater flow to these receptors as a result of the cutting.

5.2.14 In the southern part of the cutting, where flow is to the east, there will be no significant effects on spring flows (Sp2 and Sp3) which arise to the south of the cutting. The unlicensed abstraction and spring at Bungalow Farm (Sp5) will also not be significantly affected as the groundwater divide is to the east of the route at this point and while the divide may shift westwards the overall flow to the spring is unlikely to be substantially disturbed.

5.2.15 The springs to the south-west of the northern part of the cutting issue to the west of the cutting and are outside the zone of influence (SP4, 6 and 7). The amount of dewatering in this part of the cutting is also likely to be small (0-4m) and close to zero during dry conditions.

5.2.16 There is a spring at Greatworth Hall (SP7), at this point the route is on embankment across the valley within which SP7 is located. The nearest section of Greatworth South cutting is close to ground elevation and there will be negligible dewatering of the aquifer to disturb flow at this spring.

5.2.17 Track drainage will also be discharged to the existing minor watercourse south of Halse Copse via a balancing pond. This will reduce the impact on this watercourse to negligible.

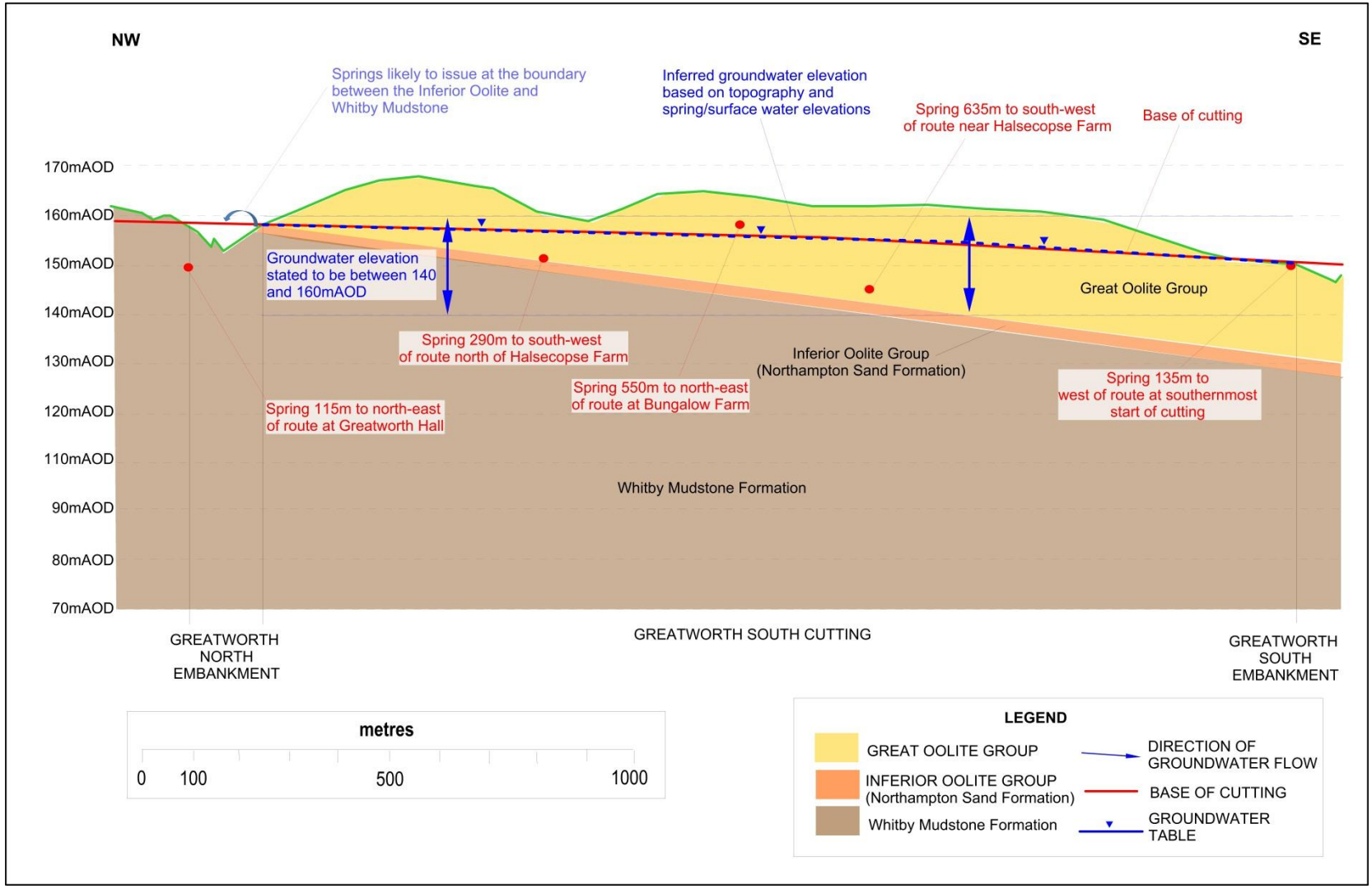
5.2.18 Surface drainage from the north-eastern side of the cutting will be directed to the minor watercourse south-east of Greatworth Fields. This will reduce the impact of any reduced spring flows on this watercourse.

5.2.19 Groundwater intercepted by the cutting will be collected by the track drainage and discharged to the watercourse south of Halse Copse 1.5km further east. Following the application of this mitigation a slight effect is anticipated.

5.2.20 In conclusion, whilst there could be some loss of flow to springs it is anticipated that this will not be significant during normal groundwater conditions, or during dry periods when the water table is low.

5.2.21 During wet periods when the water table rises to the level of the cutting, there will be interception of groundwater caused by drainage in the cutting. However, the disruption to springs, spring fed streams and the spring fed abstraction will not be significantly disturbed as along the cutting the majority of the aquifer formations remain in-situ and there will be larger volumes of water available in the catchment as a whole to compensate for this minor drainage impact of the cutting.

Figure 7: Schematic cross-section of the Greatworth south cutting



Greatworth north cutting

5.2.22 A summary of the cutting details are provided in Table 14.

Table 14: Summary of Greatworth north cutting detailed groundwater assessment

Cutting parameters	Parameter details
Length (km)	0.25
Max Depth (m)	4.1
Strata Intercepted	No superficial deposits Horsehay Sand Formation (Secondary Aquifer), Great Oolite Northampton Sand Formation (Secondary Aquifer), Inferior Oolite Whitby Mudstone Formations (Unproductive Strata)
Lowest track level (m AOD)	158.4
Groundwater level(s) (m AOD)	Inferred from topography and spring elevations. Likely to be at or below base of cutting
Principal receptors	Spring 115m north-east of route at Greatworth Hall Private abstraction 885m north of cutting near Stuchbury Manor

5.2.23 The Greatworth north cutting passes through the Whitby Mudstone for the first 500m in the south before passing through the Northampton Sand and Horsehay Sand Formations. There is a spring at Greatworth Hall (SP7) as shown on Figure 8 and a private abstraction 885m north of the cutting near Stuchbury Hall, likely to abstract from the Great Oolite Group.

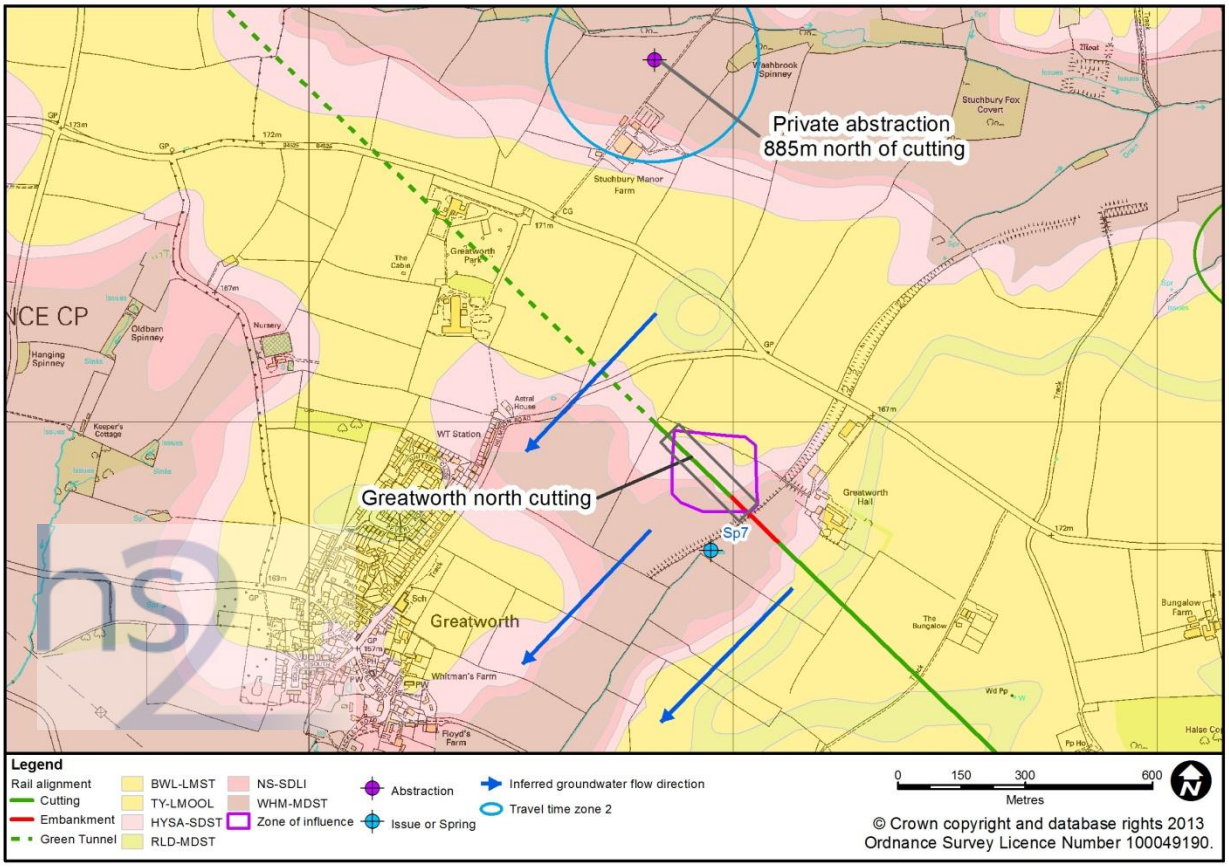
5.2.24 The groundwater elevation has been inferred from the topography and the spring elevation at Greatworth Hall (see Figure 9) and is likely to be at or below the base of the cutting. In general, therefore, there is unlikely to be any significant effect on groundwater flow. Should the water table rise above the cutting, however, the cutting could reduce the water table by up to 4m. Applying Sichardt's principals indicates that this would result in a zone of influence of no more than 190m from the cutting (Figure 8) which does not encompass any of the key receptors. Similar to the discussion for the Greatworth South cutting, this calculated zone of influence should be considered as conservative in its extent.

5.2.25 Track and land drainage will be discharged to the spring fed stream at Greatworth Hall via a balancing pond. This will ensure that there is a negligible impact on this watercourse as much of the groundwater intercepted by the track drainage will be discharged to this watercourse.

5.2.26 In summary it is anticipated there will be no significant effects to groundwater receptors within the vicinity of the Greatworth north cutting as the water table is

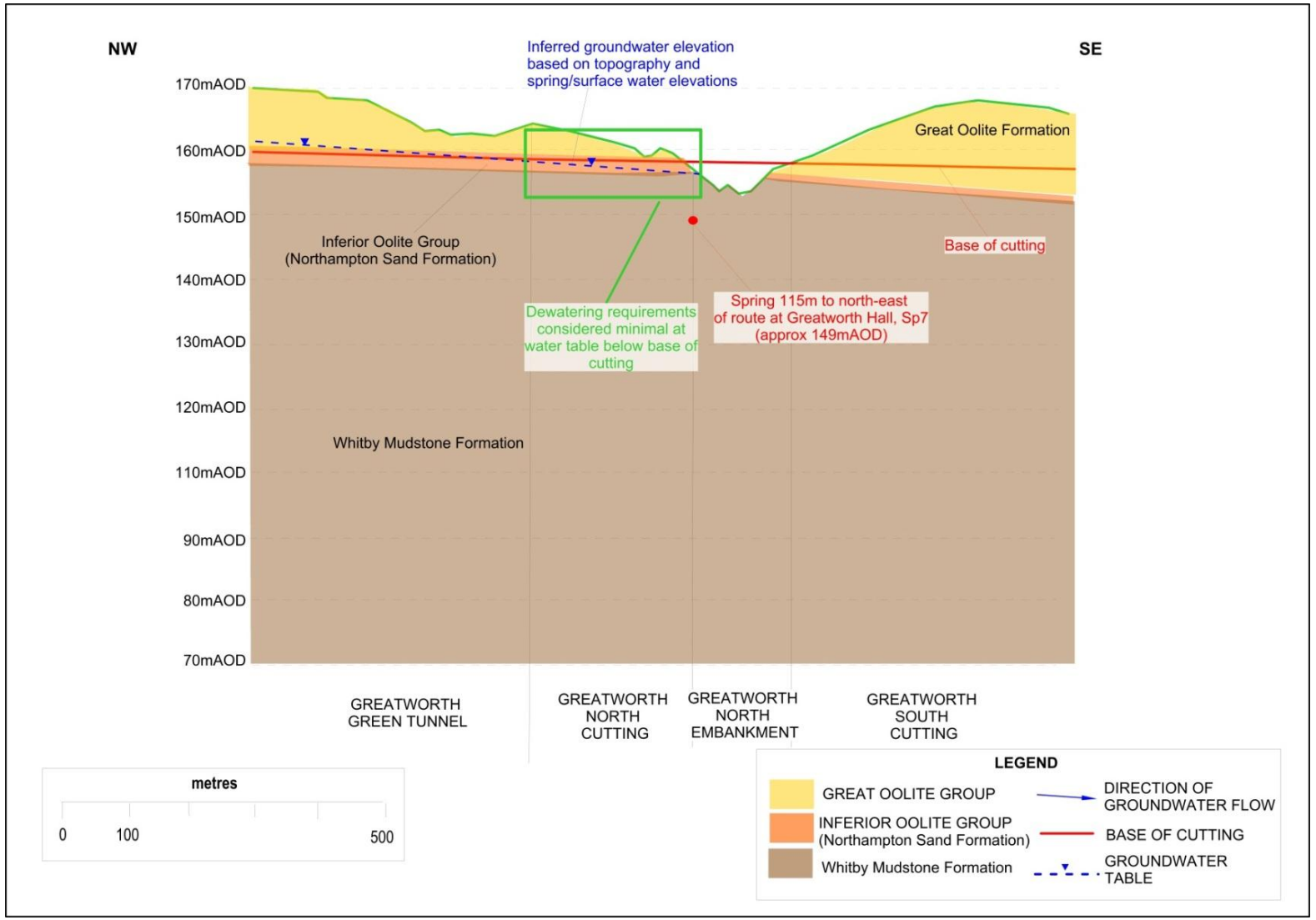
considered to be at an elevation that will only be marginally impacted by the cutting drainage and hence very little change to the groundwater flow regime.

Figure 8: Geology and key receptors of the Greatworth north cutting[15]



[15] Key to geology legend: BWL-LMST = Blisworth Limestone Formation, TY-LMOOL = Taynton Limestone Formation, HYSA-SDST = Horsehay Sand Formation, RLD-MDST = Rutland Formation - Mudstone, NS-SDLI = Northampton Sand Formation and WHM-MDST = Whitby Mudstone Formation.

Figure 9: Schematic cross-section of the Greatworth north cutting



Greatworth green tunnel

5.2.27 A summary of the cutting details are provided in Table 15.

Table 15: Summary of Greatworth green tunnel detailed groundwater assessment

Cutting parameters	**Parameter details**
Length (km)	2.1
Max Depth (m)	21.8
Strata Intercepted	Glacial Till (Unproductive) Taynton Limestone Formation (Principal aquifer) Horsehay Sand Formation (Secondary aquifer) Northampton Sand Formation (Secondary aquifer) Whitby Mudstone Formation (Unproductive)
Lowest track level (m AOD)	152.6
Groundwater level(s) (m AOD)	Inferred from topography and spring elevations. Approximately 160 - 170m
Principal receptors	Seven springs as detailed below Private abstraction 600m north of tunnel near Stuchbury Manor

5.2.28 There are limited groundwater level data available for this area and therefore groundwater flow is assumed to follow topography. The green tunnel will approximately follow a ridgeline with steep hill slopes either side of the route. The natural groundwater flow direction is expected to radiate away from this high lying land, away from the route and into the valleys.

5.2.29 The geology of the route in this area is made up of Glacial Till overlying the Great Oolite Group, viz the Taynton Limestone Formation, Horsehay Sand Formation and Northampton Sand Formation aquifers during construction. However, the springs in the vicinity of the green tunnel all emerge from the Whitby Mudstone Formation underlying the Great Oolite Group formations. Given the steep topography and the impermeable Till over much of the high lying ground it is unlikely there is significant groundwater in the Great Oolite Group, and this is bourn out by the emergence of springs and issues from the unproductive mudstone under the aquifer formations.

5.2.30 The crown of the tunnel will be approximately 8m above the rail level; the crown will be at 161m AOD at its lowest point. During construction it is assumed that the cutting would be open to its full depth.

5.2.31 Following construction it is assumed that the tunnel will be sealed and that the overlying fill would be of similar permeability to the original bedrock. The natural bedrock aquifer (Great Oolite Group) along the length of the green tunnel is considered to be relatively thin (<6m according to BGS borehole records) and the top of the completed tunnel will be at a similar elevation to that of the natural aquifer. The nature of any impacts on groundwater after the tunnel is completed would depend on

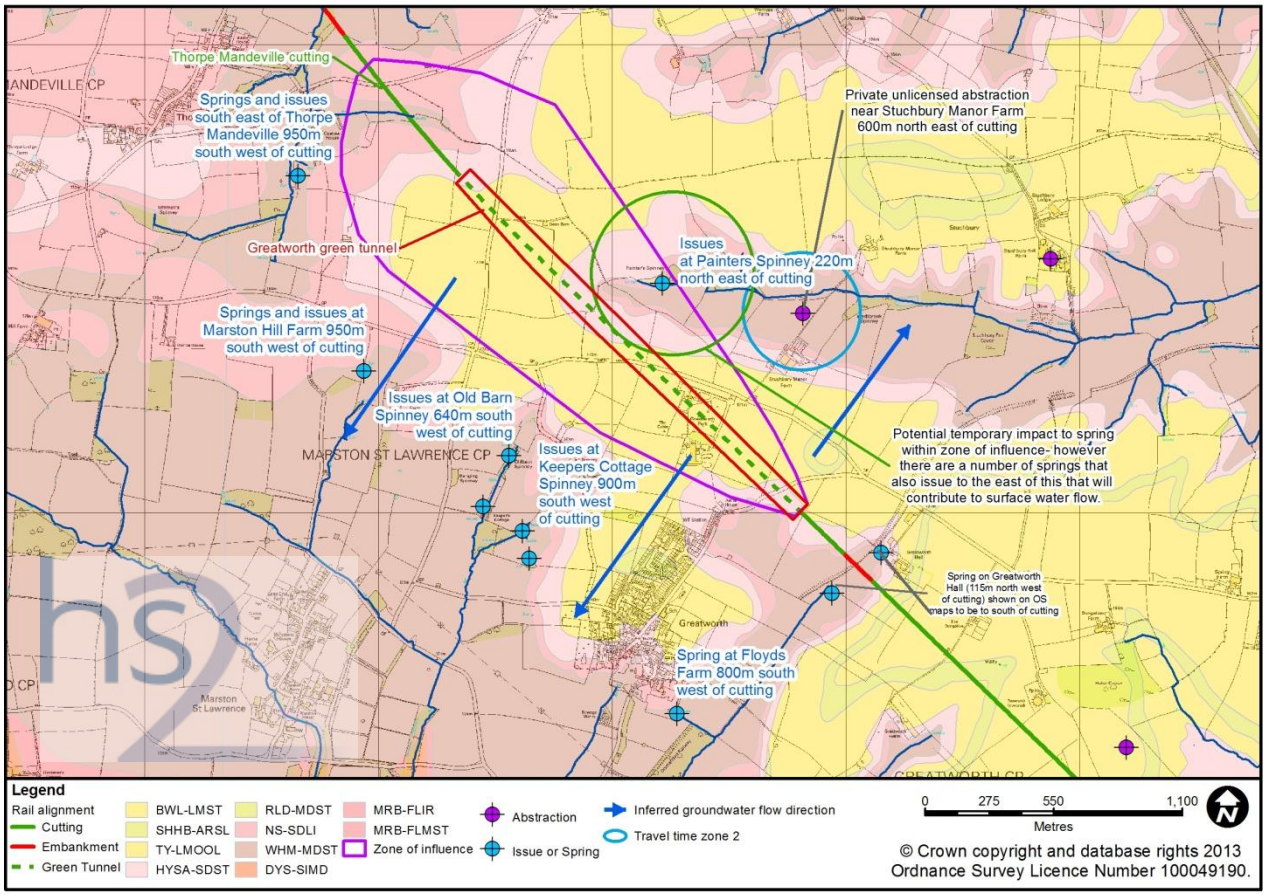
the fill material used and the groundwater levels in the Great Oolite formations. If the fill has a permeability that is too high, higher than the natural bedrock, then the green tunnel will act as a groundwater sink as groundwater will flow in high permeability fill alongside the tunnel rather than away through lower permeability aquifer in contact with the fill.

5.2.32 If a lower permeability fill is used then the tunnel is unlikely to significantly affect natural groundwater flow which would tend to flow away from the route.

5.2.33 There are numerous springs from the base of the Northampton Sand Formation and within the Whitby Mudstone Formation that feed into minor watercourses that flow into the River Tove to the north and the River Cherwell to the south. These springs are considered to be moderate value receptors.

5.2.34 Figure 10 illustrates the key receptors that could be affected by the cutting and an approximate zone of influence based on maximum potential groundwater elevations. The zone of influence considers the combined impact from the Greatworth green tunnel and the adjacent Thorpe Mandeville cutting during construction. Following completion of the green tunnel, only the Thorpe Mandeville cutting will continue to act as a potential groundwater sink. As such, the zone of influence will be focussed around the Thorpe Mandeville cutting only, thereby reducing its spatial extent significantly. There is only one receptor within the zone of influence - the issues at Painters Spinney, 220m north-east of the tunnel.

Figure 10: Geology and key receptors within the vicinity of the Greatworth green tunnel[16]



5.2.35 The impacts on these springs are summarised in Table 16.

Table 16: Impact of the Greatworth green tunnel on springs and issues

Location	Formation	Description	Impact	Effect
Issues south of Floyds Farm approximately 800m south-west of the route	Northampton Sand Formation/ Whitby Mudstone	Groundwater flow to this spring will be largely from the area of Greatworth itself but there may be a contribution from limestone to the north of the village. The green tunnel cuts through the Taynton Limestone, Horsehay and Northampton Sand Formations to the north of Greatworth. During construction any groundwater in these formations would be drawn towards and intercepted by the cutting for the green tunnel. The distance of this spring from the route and its emergence from the Whitby Mustone formation well below the green tunnel elevation indicates there is not likely to be any impact on flow from this spring.	Negligible (temporary) Negligible (permanent)	Neutral (temporary) Neutral (permanent)

[16] Key to geology legend: BWL-LMST = Blisworth Limestone Formation, SHHB-ARSL = Sharp's Hill Formation, TY-LMOOL = Taynton Limestone Formation, HYSA-SDST = Horsehay Sand Formation, RLD-MDST = Rutland Formation - Mudstone, NS-SDLI = Northampton Sand Formation, WHM-MDST = Whitby Mudstone Formation, DYS-SIMD = Dyrham Formation, MRB-FLIR = Marlstone Rock Formation - Ferruginous Limestone and Ironstone and MRB-FLMST = Marlstone Rock Formation - Limestone, Ferruginous.

Location	Formation	Description	Impact	Effect
Issues at Oldbarn Spinney, approximately 640m south-west of the route and at Keepers Cottage approximately 900m south-west of the route (all in close proximity to each other in the same valley feature)	Northampton Sand Formation/ Whitby Mudstone	Groundwater flow to this spring is from the north and north-east and the spring emerges at about 155mAOD from the Whitby Mudstone Formation. The springs at Keepers Cottage emerge lower down the hillside below 150mAOD. The green tunnel at this location is above the elevation of the spring and there is a groundwater divide along the line of the ridge between this spring and the proposed scheme. During construction the position of this groundwater divide may be shifted slightly due to the interception of groundwater by cutting for the green tunnel, and whilst this may cause a small reduction in flow from this spring it is considered to be a negligible impact. During operation the green tunnel would be sealed and groundwater flow towards this spring will be restored.	Minor (temporary) Negligible (permanent)	Slight (temporary) Neutral (permanent)
Spring at Painters Spinney approximately 220m north-east of the route	Northampton Sand Formation/ Whitby Mudstone	The issues emerge at about 162mAOD from the Whitby Mudstone Formation. Groundwater flow to this spring is expected to be primarily from the north and north-east with some flow from the west (ie. from the route area). Some groundwater flow could be disrupted as a result of the tunnel acting as a sink during construction. The proportion of groundwater feeding the spring likely to be affected is considered to be relatively small, although the effect would be moderate. Following construction of the green tunnel, the overlying material will allow for natural flow to be reinstated.	Moderate (temporary) Negligible (permanent)	Moderate (temporary) Neutral (permanent)
Springs and issues at Marston Hill Farm approximately 950m south-west of the route	Northampton Sand Formation/ Whitby Mudstone	The spring emerges at an elevation of 160mAOD and on the opposite side of a ridge from where the route will be constructed. Groundwater flow to this spring is expected to be from the north-east and north-west. During construction the green tunnel would act as a groundwater sink and divert groundwater that would otherwise flow to this spring, although the proportion of groundwater intercepted that flows to this spring is not considered to significantly affect flow to the spring. No adverse effects are anticipated following construction.	Minor (temporary) Negligible (permanent)	Slight (temporary) Neutral (permanent)

Location	Formation	Description	Impact	Effect
Springs and issues south-east of Thorpe Mandeville, south of Costow House approximately 840m south-west of the route	Northampton Sand Formation/ Whitby Mudstone	Springs emerge at about 150mAOD in this small valley feature. Groundwater flow to this spring and groundwater baseflow to the stream to the north is derived the Whitby Mudstone and probably from infiltration from overlying Taynton Limestone, Horsehay and Northampton Sand Formations to the east. During construction some groundwater could be drawn towards the green tunnel causing a minor reduction in flow to this spring and stream. No impact is expected following the construction of the proposed scheme.	Minor (temporary) Negligible (permanent)	Slight (temporary) Neutral (permanent)

5.2.36 An unlicensed groundwater abstraction from a spring source is recorded near Stuchbury Manor Farm, 600m north-east of the route. The topographic contours suggest that a groundwater divide is currently located between the abstraction and the route, to the north-east of the route. During construction the groundwater divide may shift as a result of the cutting acting as a groundwater sink. As such, there could be some reduction in flow to the spring fed source although it is unlikely that the spring will be significantly affected, particularly following construction. The spring is at an elevation of approximately 155m AOD which is below the elevation of the cutting at this point. It is predicted that the green tunnel will result in a minor impact and slight effect during construction, which, with placement of suitable materials above the tunnel will be negligible and neutral following construction.

5.2.37 In addition to the springs and abstractions there are four surface water features (ponds) within the zone of influence - one to the south of the southern section of the green tunnel which is on the boundary of the zone of influence; one to the west of the tunnel by the side of the road to Greatworth Hall; one to the east of the tunnel near Costow House; and one to the east of the tunnel near Dean Barn. There could, therefore, be an effect on water levels in these ponds, although only during construction.

5.2.38 During operation the limited volume of track drainage will be directed to minor watercourses feeding the River Cherwell via balancing ponds at the western end of the green tunnel. It is anticipated that similar arrangements will be in place during the construction phase.

5.2.39 Track and land drainage would be discharged to the southwest of Greatworth Hall via a balancing pond. This would ensure that there is a negligible impact on this watercourse.

Thorpe Mandeville cutting

5.2.40 A summary of the cutting details are provided in Table 17.

Table 17: Summary of Thorpe Mandeville cutting detailed groundwater assessment

Cutting parameters	Parameter details
Length (km)	0.75
Max Depth (m)	16.0
Strata Intercepted	Horsehay Sand Formation (Secondary aquifer) Northampton Sand Formation (Secondary aquifer) Whitby Mudstone Formation (Unproductive)
Lowest track level (m AOD)	146.0
Groundwater level(s) (m AOD)	Inferred from topography and spring elevations. Approximately 140 – 155
Principal receptors	Four springs near Whitnell's Spinney Two issues west of Magpie Farm Two springs/issues south of Costow House

5.2.41 There is the potential for the cutting to drain parts of the Horsehay Sand and Northampton Sand Formations during construction and operation if the base of the cutting is below the anticipated groundwater level. There is not sufficient groundwater level data available to determine the quantity of groundwater that would be intercepted.

5.2.42 Groundwater flow is assumed to follow topography, generally flowing to the north and north-west to the east of the scheme and in a westward direction to the west of the scheme, converging on the source of the Culworth Brook, a tributary of the River Cherwell.

5.2.43 There are four springs/issues near Whitnell's Spinney to the west/south-west of the scheme that issue from the deeper Whitby Mudstone Formation and from the Northampton Sand Formation. Groundwater flow to these springs is likely to be mainly from the west with only some flow being contributed from the higher lying ground near the scheme. As such they will not be affected significantly by the scheme.

5.2.44 Similarly, there are two issues to the west of Magpie Farm, to the north-east of the scheme, that are likely to be fed from the east and north-east and east and will not be affected by the cutting.

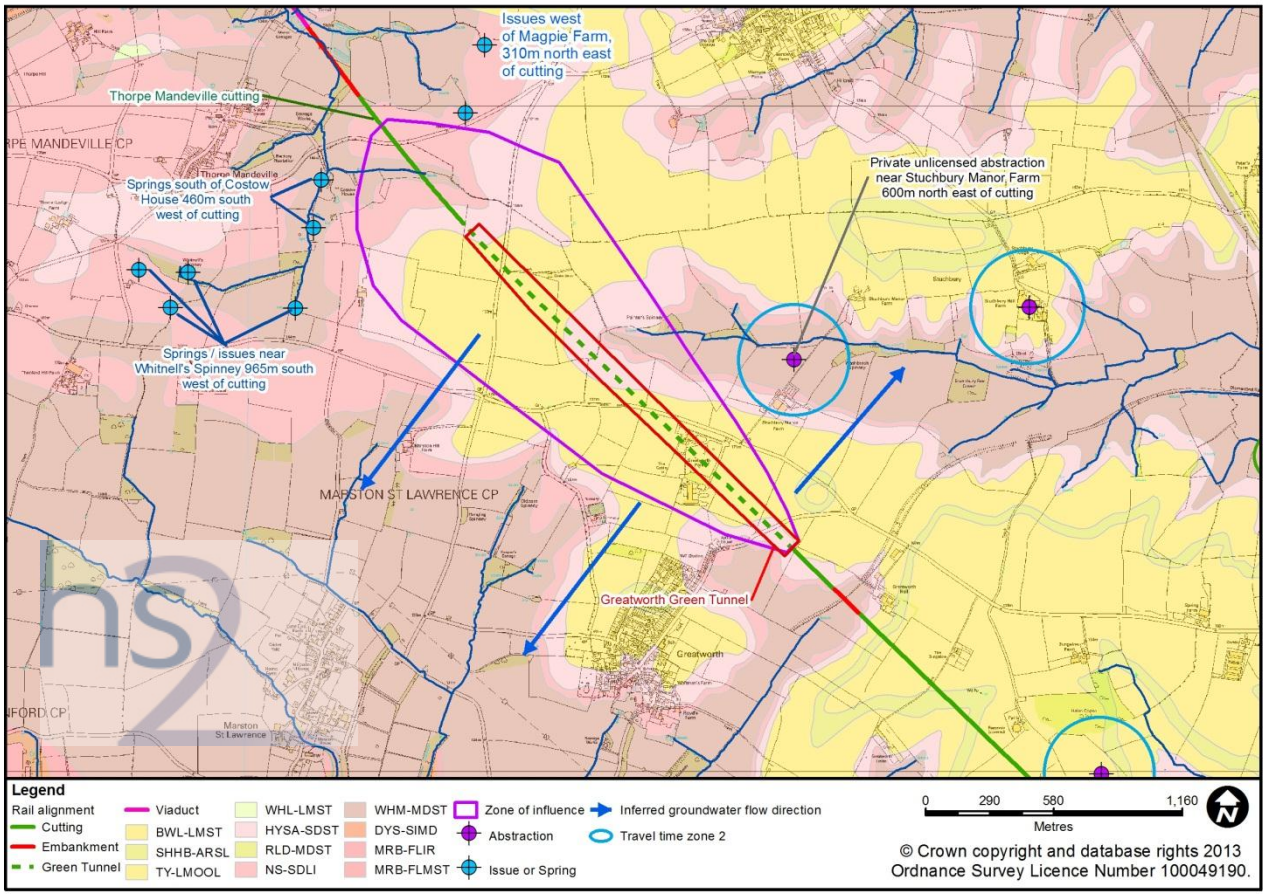
5.2.45 There are two springs/issues immediately south of Costow House (460m south-west of the cutting) and another issue noted as being almost on the route to the east of Costow House (SWC-CFA15-01). A stream flows from the issue at SWC-CFA15-01 which feeds a water dependant habitat, classified as a potential wildlife site in that area.

5.2.46 The zone of influence has been estimated using Sichardt's formula and is shown on Figure 11. The zone of influence is combined with the neighbouring Greatworth green tunnel as they will have a combined impact during construction. Following construction, the impact of the green tunnel will significantly reduce as the tunnel will no longer act as a sink but rather a partial barrier. The zone of influence of the Thorpe Mandeville cutting would, therefore, reduce.

5.2.47 It is predicted that the presence of the cutting will lower groundwater levels to approximately 150m AOD, resulting in a significant drop in baseflow along the upper 200m of this watercourse. The reduction in flow would be a moderate impact resulting in a large effect on the short section of watercourse.

5.2.48 Other than the issue at SWC-CFA15-01 there are no key receptors within the zone of influence. The two springs 460m from the route could have a reduced catchment supplying them as a result of the cutting being in place, assessed to be a moderate impact and a moderate effect from the cutting.

Figure 11: Geology and key receptors within the vicinity of the Thorpe Mandeville cutting[17]



5.2.49 The scheme design incorporates returning any groundwater intercepted by the Thorpe Mandeville Cutting to upper reaches of the Culworth Brook north-east of Thorpe Mandeville. It is anticipated, however, that there will still be a reduction of

[17] Key to geology legend: BWL-LMST = Blisworth Limestone Formation, SHHB-ARSL = Sharp's Hill Formation, TY-LMOOL = Taynton Limestone Formation, HYSA-SDST = Horsehay Sand Formation, RLD-MDST = Rutland Formation - Mudstone, NS-SDLI = Northampton Sand Formation, WHM-MDST = Whitby Mudstone Formation, DYS-SIMD = Dyrham Formation, MRB-FLIR = Marlstone Rock Formation - Ferruginous Limestone and Ironstone and MRB-FLMST = Marlstone Rock Formation - Limestone, Ferruginous.

baseflow to the upper 800m of this watercourse which may have an impact on the potential water dependent habitat. There is no further practical mitigation that can be taken for the loss of the issue near Costow House (SWC-CFA15-01) or the reduction in flows to the two springs to the south of Costow House, which will result in a permanent moderate adverse effect.

Edgcote cutting

5.2.50 A summary of the cutting details are provided in Table 18.

Table 18: Summary of Edgcote cutting detailed groundwater assessment

Cutting parameters	**Parameter details**
Length (km)	0.93
Max Depth (m)	5.6
Strata Intercepted	Marlstone Rock Formation (Secondary aquifer) Dyrham Formation (Secondary aquifer)
Lowest track level (m AOD)	117.3
Groundwater level(s) (m AOD)	Inferred from topography and spring elevations.
Principal receptors	Springs; 100m south-west of route, 440m south-west of route and 470m south-west.

5.2.51 There is the potential for the cutting to drain parts of the Marlstone Rock Formation and Dyrham Formation aquifers if the base of the cutting is below the groundwater level. There is not sufficient groundwater level data to determine whether any groundwater would be intercepted.

5.2.52 An approximate zone of influence has been estimated using Sichardt's equation which indicates that the influence on groundwater could be up to 145m from the cutting (see Figure 12). The zone of influence is combined with the neighbouring Chipping Warden green tunnel (to the north) as they will have a combined impact during construction. Following construction the impact of the green tunnel will significantly reduce as the tunnel will no longer act as a sink but rather a partial barrier. The permanent zone of influence of the Edgcote cutting would therefore reduce.

5.2.53 There are three springs marked on some of the OS maps that emerge in the River Cherwell valley from the underlying Charmouth Mudstone Formation - the River Cherwell is a high value receptor. The closest spring is 100m south-west where it moves from embankment into the Edgecote cutting. It is marked on some of the OS maps, but not on more detailed OS maps and cannot be seen on aerial photographs, so it is likely to be a minor ephemeral feature with a low value. The spring is marked close to an area called the Osierbed Spinnery - which indicates the valley floor near the river channel is boggy. At the immediate entry of the cutting it is not likely to be intersecting groundwater as it is very shallow. This small ephemeral spring is likely to be fed from a small groundwater catchment local to its emergence. This could be a minor impact on groundwater flow in the area if the cutting drainage intersected

groundwater during wet periods. The impact on this spring is likely to be moderate with a slight effect (not significant).

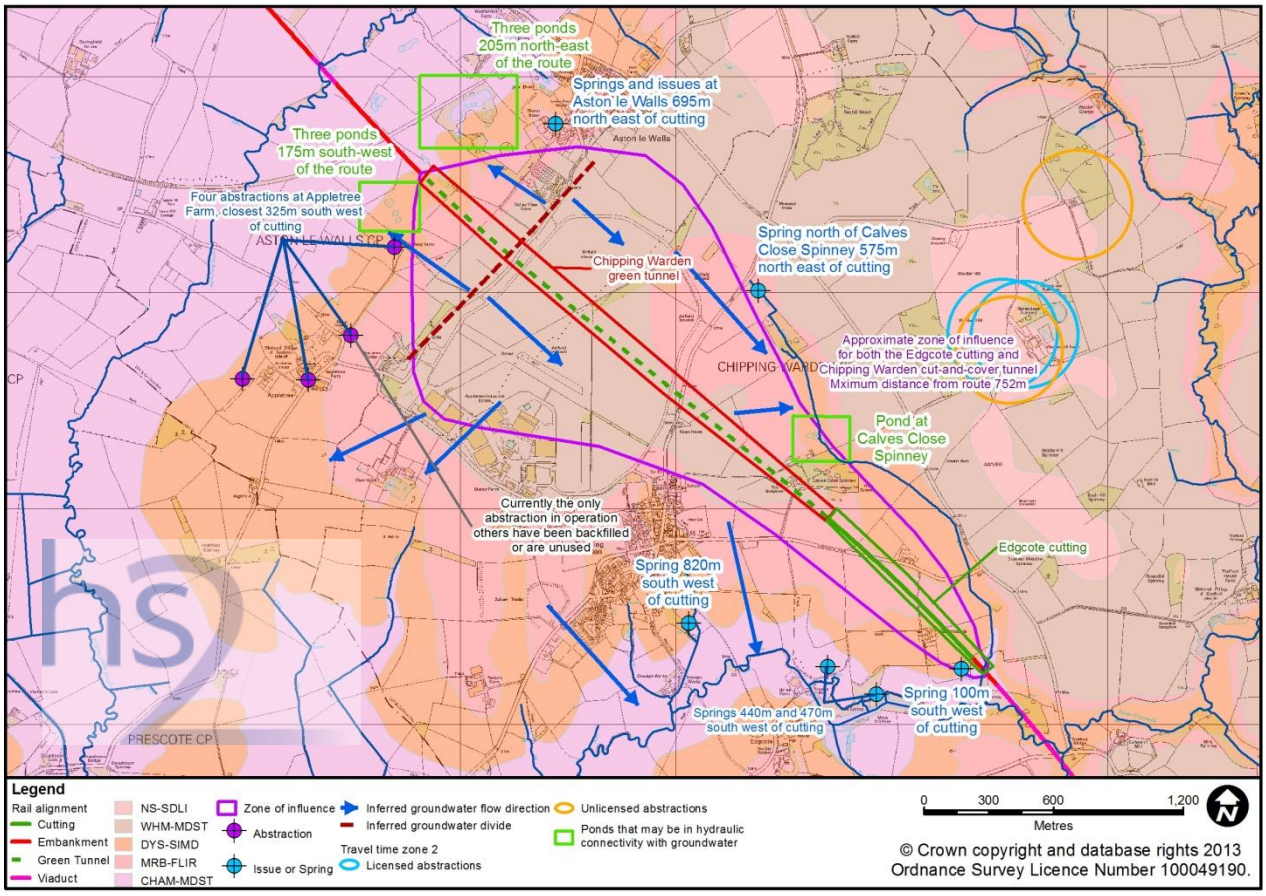
5.2.54 The two other springs that are approximately 440m south-west of the route and approximately 470m south-west of the route are located very close to the river channel itself (within 20m of the river channel). These emerge from the Charmouth Mudstone Formation so are not likely to have large catchments feeding them. They are also well outside the potential zone of influence of the cutting so any impact on groundwater flow to them will be limited. The impact is likely to be minor which would result in a slight effect (not significant).

5.2.55 There are other springs over 800m to the west and south-west of the cutting that will not be impacted as topographic contours indicate they are likely to be fed by groundwater that will not be disrupted by the Edgecote cutting.

5.2.56 Land and track drainage from the cutting will be discharged to the River Cherwell and some of its tributaries via balancing ponds. This will ensure that there will be a negligible impact on the flow in the River Cherwell.

5.2.57 A minor watercourse rises to the north-east of the route (north-west of Calves Close Spinney) approximately 500m south of the Welsh Road and A361 road junction. This watercourse is likely to be fed primarily from the high ground located to the north-east of the route. Some groundwater flow to this watercourse from the south-west, however, could be drawn into this cutting. This is predicted to be a minor impact on this moderate value receptor resulting in a slight effect (Not significant).

Figure 12: Geology and key receptors within the vicinity of the Edgcote cutting and Chipping Warden green tunnel[18]



Chipping Warden green tunnel

5.2.58 A summary of the cutting details are provided in Table 19.

Table 19: Summary of Chipping Warden green tunnel detailed groundwater assessment

Length (km)	2.47
Max Depth (m)	23.6
Strata Intercepted	Whitby Mudstone Formation (Unproductive) Marlstone Rock Formation (Secondary aquifer) Dyrham Formation (Secondary aquifer)
Lowest track level (m AOD)	119.6
Groundwater level(s) (m AOD)	125 to 140
Principal receptors	Springs, ponds and four abstractions near Appletree Farm. Pond at Calves Close Spinney.

[18] Key to geology legend: NS-SDLI = Northampton Sand Formation, WHM-MDST = Whitby Mudstone Formation, DYS-SIMD = Dyrham Formation, MRB-FLIR = Marlstone Rock Formation and CHAM-MDST = Charmouth Mudstone Formation.

5.2.59 Water levels at Appletree Farm are recorded as being 15m below the well top – indicating groundwater elevation is around 130m AOD. There is limited groundwater level data currently available for the remainder of this area and therefore groundwater flow is assumed to follow topography. There is an assumed groundwater divide running from Aston le Walls to Appletree (see Figure 12).

5.2.60 South-east of the groundwater divide the natural groundwater flow direction is assumed to be to the south-east, parallel to the route. North-west of this divide the natural groundwater flow direction is expected to be towards the north-west, parallel to the route.

5.2.61 There is the potential for the green tunnel to drain parts of the Marlstone Rock Formation and Dyrham Formation aquifers during construction as the base of the cutting is below the anticipated groundwater level. Groundwater flow will be drawn towards the open cutting. There are insufficient data available to quantify the volume of groundwater that will be intercepted.

5.2.62 Figure 12 illustrates the key receptors that could be affected by the cutting and an approximate zone of influence based on maximum potential groundwater elevations. The zone of influence is combined with the adjacent Edgcote cutting to the south, as both design elements will impact the groundwater flow at the same time during construction, before the green tunnel is completed.

5.2.63 The crown of the tunnel will be 8m above the rail level, 127.6m AOD at its lowest point and, based on the water elevation data available may be marginally lower than the groundwater elevation. During construction it is assumed that the cutting will be open and will require dewatering. Following construction, however, it is assumed that the tunnel itself will be sealed and that the overlying fill material will be of similar permeability to the original bedrock. The nature of any impacts will depend on the fill material used. If the fill material has a higher permeability than the bedrock then the green tunnel will continue to act as a groundwater sink.

5.2.64 The minor watercourse rising to the north-east of the Proposed Scheme route (north-west of Calves Close Spinney) is likely to be fed primarily from the high ground located to the north-east of the route. Some groundwater may flow to this watercourse from the south-west. This groundwater is likely to be drawn into the cutting for the Chipping Warden green tunnel during construction. This would be a minor impact on this moderate value receptor. As such, there will be a slight temporary effect. Following construction the green tunnel would be sealed and the natural groundwater flow regime will be restored.

5.2.65 There is also pond on the boundary of the zone of influence, located north-east of the route and north of Calves Close Spinney. This pond sits at a relatively high elevation on the permeable Dyrham Formation so is likely to be sealed by locally low permeable materials. The zone of influence will, however, be reduced following construction and the pond will not be significantly affected once the green tunnel is complete.

5.2.66 Several small watercourses rise to the south-east of Chipping Warden. These watercourses arise from springs or issues from within the outcrop of the Dyrham Formation or from the base of the outcrop. During construction of the green tunnel some groundwater in the Dyrham Formation feeding these springs will be drawn into

the works area and this could slightly reduce flows to these features. It is anticipated there will be at most a moderate impact on these moderate value receptors resulting in a moderate effect.

5.2.67 There are three ponds north of Field Farm (Aston Le Walls) which will be approximately 175m south-west of the route and another three ponds north of Valley View Farm (Aston Le Walls) that will be approximately 205m north-east of the route. The ponds lie above the Dyrham Formation and are potentially in hydraulic connectivity with the groundwater. The ponds are outside the zone of influence but may experience a reduction in contributing groundwater flow as a result of the construction of the green tunnel, which could be moderate. The resulting slight effect on these low value receptors would not be significant. Groundwater flow towards the ponds would recover to normal levels once the green tunnel is complete.

5.2.68 There are four abstractions within the vicinity of Appletree Farm that could be affected by the tunnel (see Figure 12). This is likely to occur only during construction when the green tunnel is open and will act as a sink to groundwater flow. The borehole closest to the tunnel (i.e. 330m south-west) is not currently used so, whilst the published travel time zone 2 is intersected by the zone of influence, the source is no longer in use and will not be adversely effected. The two furthest sources from the scheme are also not in use and so will not be affected by the Proposed Scheme.

5.2.69 The borehole currently operational is located approximately 760m from the scheme. During construction of the green tunnel groundwater in the area which might normal supply the abstraction could be diverted towards the excavated tunnel. This would be a moderate impact and a moderate effect, and therefore significant. Monitoring will be required prior to construction to determine groundwater flow patterns in the area of the cutting and the abstraction borehole.

5.2.70 Based on the results of the monitoring mitigation to be applied before construction could be available permanently. Possible mitigation includes deepening pump setting in the borehole, possibly deepening a borehole, reinstating one of the boreholes further away for use or putting the farm onto the mains supply if none of the above are practicable. The range of options will be discussed and agreed with the licence holder. Following application of appropriate mitigation before construction of the green tunnel, should it be required, there will be a negligible impact on the operations of the licence holder, and no permanent significant effects on the abstraction licence holder at Appletree.

5.2.71 Following completion of the green tunnel the tunnel will no longer act as a sink and there will not be any significant adverse effects on these abstractions.

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